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Effect of Nano NPK Fertilizers on Growth and Fruit Quality of Sapota (*Manilkara achras* Mill Fosberg) Cv. Kalipatti

Priyanka Mirji[1]*, Srinivasappa K.N.[2], Venkatesha Murthy P.[3], Thimmarayappa M[4], Ramachandra C.T.[5] and Mohan Kumar T.L.[6]

Department of Horticulture, College of Agriculture, UAS, GKVK, Bengaluru 560 065, Karnataka, India

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ABSTRACT

The study was conducted in the Department of Horticulture, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru during the year 2020-2022 to investigate the "Effect of nano NPK fertilizers on growth and fruit quality of sapota (*Manilkara achras* Mill Fosberg) Cv. Kalipatti". The experiment was planned with randomized complete block design (RCBD) consisting of 12 treatments and 3 replications. During both the years (2020-2021 and 2021-2022) as well as from pooled data indicates that the maximum plant height (3.64 m, 3.78m and 3.71 m respectively), plant spread at East-West direction (8.26 m, 9.40 m and 8.83 m respectively) and North- South direction (8.24 m, 8.71m and 8.48m respectively) was noticed in the treatment T_{10} (50% RDF + 0.3% Nano NPK fertilizer foliar spray) and maximum chlorophyll content (2.30 mg/ g) was noticed in the treatment T_9 (50% RDF + 0.2% Nano NPK fertilizer foliar spray) during the year 2021-2022. The maximum values for quality parameters like TSS (22.33 ^{o}Brix), reducing sugar (9.31 %), total sugars (22.18 %), shelf life of fruits (7 days) and fruit firmness (74 N) were noticed in treatment T_9 (50 per cent of RDF and foliar application of 0.2% of nano NPK fertilizer) during the year 2021-2022 . Among all the different treatments T_{10} (50 per cent of RDF and foliar application of 0.3% of nano NPK fertilizer) and T_9 (50 per cent of RDF and foliar application of 0.2% of nano NPK fertilizer) were proved significant improvement fortree growth and fruit quality of sapota respectively.

Key words: *Nano-fertilizers, NPK, RDF, Sapota and Foliar spray*

Introduction

Sapota (*Manilkara achras* Mill Fosberg.) native of Mexico belongs to the botanical family Sapotaceae. It is mainly introduced for its delicious fruits. Many fruit growers were attracted to the cultivation of sapota on account of its better adaptation to diverse soil and climatic conditions. It is getting popular in countries *viz*., India, Sri Lanka, Jamaica, Burma, The Philippines, Central Asia and Southern Florida (USA).

It is gaining more importance in the tropical, subtropical and semiarid climate. It can also sustain waste land and marginal lands, but fruit set, yield and the economy were inferior due to improper nutrition. This crop also suffers from a malady called mummification or stone fruit, is very severe in old orchards in certain areas of hill zones. The severity leads to a loss of crop to the tune of more than 70 per cent (Satish, 2003).

The successful commercial cultivation of this crop depends on many factors such as climate, soil, irriga-

tion, fertilizer, spacing and season of growing etc. Among the different management practices, nutrient management plays an important role in growth, yield and economy of fruit crop. To perform sustainable yield and economy, it needs high amount of nutrients (Mishra, 2014).

The intensive and exploitative agriculture with high inputs and high yielding varieties and improved technologies, have helped for better fruit production. But, competition for water and nutrients and the major nutrients usually supplied through straight fertilizers in large quantities for improving fruit set, productivity and to meet nutritional requirement of the fruit trees. But, application of straight fertilizers leads to evaporation, leaching and run off of nutrients. Hence, the experiments have been conducted to reduce the nutrient losses and increase the nutrient use efficiency of fertilizers through use of nano-fertilizers. These nano-fertilizers shown significantly improved yield in different fruit crops .Therefore, based on the possible benefits of soil and foliar application of nano-fertilizers (NFs) seems to be benificial.

Nano-fertilizers (NFs) are widely used in fruit crop nutrition as soil based and spraybased applications that provide nutrients with high efficiency and low waste due to their faster and higher translocation to different parts of plants. After penetrating the leaf or root cuticle tissue, NFs move through different pathways (apoplastic, symplastic, lipophilic and hydrophilic), which influence their effectiveness, final fate and may also change their properties and reactivity, delivery and translocation inside plant tissues, which may result in various responses of different plant parts to the same NP (Nano Particle).

NFs are much smaller than conventional materials and due to a greater surface areatoweight ratio, different shapes and higher penetrability, they may have more significant effects on growth and developmental processes and can directly enter leaf tissues through stomata. The concentration and consumption time of NFs can influence their effects on plants and different plant processes. Due to their tiny scale, NPs have high penetrability into plant tissues and high concentrations of NFs may negatively affect growth and development. To prevent these negative effects, they are generally applied in very low concentrations at the mgl^{-1} level. Therefore, to achieve higher yield and lower damage applied in lower concentration to reach required nutrients by the plants, also reduce the use of large amount of inorganic fertilizers (50%) in conventional method and reduce the cost of about 10% compared to conventional fertilizers.

Materials and Methods

A field study on "Effect of nano NPK fertilizers on plant growth and quality of sapota fruits Cv. Kalipatti" was initiated during 2020- 2022. The experiment was conducted in the Department of Horticulture, UAS, GKVK, Bengaluru. The experiment site is situated in Eastern dry zone (Zone-5) of Karnataka State at 13°05" North latitude and 77° 34" East longitude with an elevation of about 924 meters above mean sea level. The major rainfall received from South- West monsoon between June to September months and North- East monsoon between October to December months.

The experiment was laid out in Complete Randomized Block Design (RCBD) with twelve treatments and three replications consisting of different concentrations of nano fertilizers and RDF application for sapota trees. Sapota trees were planted at distance of 10 x 10m (Standing crop). The treatments were **T_1-** Control (RDF 400: 160: 150 g/plant), **T_2-** Water soluble normal fertilizers foliar spray (NPK fertilizer),**T_3-** 25% RDF (100: 40: 37 g/plant) + 0.1% Nano NPK fertilizer foliar spray, **T_4-** 25% RDF + 0.2% Nano NPK fertilizer foliar spray, **T_5-** 25% RDF + 0.3% Nano NPK fertilizer foliar spray, **T_6-** 25% RDF + 0.4% Nano NPK fertilizer foliar spray, **T_7-** 25% RDF + 0.5% Nano NPK fertilizer foliar spray, **T_8-** 50% RDF (200: 80: 75 g/plant) + 0.1% Nano NPK fertilizer foliar spray, **T_9-** 50% RDF + 0.2% Nano NPK fertilizer foliar spray, **T_{10}-** 50% RDF + 0.3% Nano NPK fertilizer foliar spray, **T_{11}-** 50% RDF + 0.4% Nano NPK fertilizer foliar spray, **T_{12}-** 50% RDF + 0.5% Nano NPK fertilizer foliar spray.

The treatments were imposed to sapota trees in split application and first imposition was done through foliar application of nano NPK fertilizers for three times- first at the end of last season harvest, second spray at one month after the first spray and third spray when fruit lets were at pea size and soil application of RDF was at a once. Other cultural operations were attended to keep the plot clean and plant protection measures were carried out at regular intervals.

Results

Growth parameters

Plant height

The plant height of sapota tree as influenced by different concentrations of nano-fertilizer along with varied per cent of RDF during both the year 2020-21 and 2021-2022 as well as pooled data is presented in Table 1.

Among all the treatments, T_{10} consists of 50% of Recommended Dose Fertilizer (RDF) with foliar application of 0.3% of nano NPK fertilizer recorded significantly maximum plant height for both the seasons (3.64 m and 3.78 m respectively) which was on par (3.58 m and 3.73 m respectively) with T_9 while, minimum plant height was recorded in treatment T_1 (only RDF application) with 2.81 m and 2.93 m respectively for both seasons (2020-2021 and 2021-2022). From analysed pooled data that the maximum plant height (3.71 m) was observed in the treatment T_{10} which was found on par (3.66 m) with T_9 and lowest plant height was recorded in T_1 (2.87 m).

Chlorophyll content

Foliar application of different concentrations of nano-fertilizer along with varied per cent of RDF had significant influence on chlorophyll content of sapota leaves during both the years 2020-21 and 2021-2022 as well as pooled data.

During the year 2020-2021 significantly higher chlorophyll content of sapota leaves was recorded in the treatment T_8 (2.13 mg/g) and during the year 2021-2022 maximum chlorophyll content was observed in T_9(2.30 mg/g). Less chlorophyll content was observed during both the years 2020-2021 and 2021-22 in treatment T_1(1.78 mg/g and 1.98 mg/g respectively). It was evident from the pooled data that the maximum value was recorded in treatment T_8(2.17 mg/g). Chlorophyll content was observed least in treatment T_1 and T_3(1.88 mg/g).

Plant spread

Plant spread at East-West and North-South direction of sapota tree as influenced by different concentrations of nano-fertilizer along with varied per cent

Table 1. Effect of nano NPK fertilizer on plant height and chlorophyll content of sapota

Treatments	Plant height (m)			Chlorophyll content (mg/g)		
	2021	2022	Pooled	2021	2022	Pooled
T_1	2.81^{f}	2.93^{e}	2.87^{g}	1.78^{e}	1.98^{bcd}	1.88^{ef}
T_2	2.94^{ef}	3^{e}	2.97^{fg}	1.87^{cde}	1.98^{bcd}	1.98^{abcde}
T_3	2.97^{e}	3.1^{e}	3.03^{f}	1.84^{de}	1.93^{cd}	1.88^{ef}
T_4	3.43^{bc}	3.53^{c}	3.48^{cd}	1.89^{bcde}	1.97^{bcd}	1.93^{bcdef}
T_5	3.41^{bc}	3.6^{abc}	3.51^{cd}	2.06^{abc}	2.05^{bcd}	2.1^{abc}
T_6	3.53^{ab}	3.67^{abc}	3.6^{abc}	1.99^{abcd}	2.03^{bcd}	2.05^{abcde}
T_7	3.38^{c}	3.55^{bc}	3.46^{cd}	2.07^{abc}	2.03^{bcd}	2.1^{abcd}
T_8	3.44^{bc}	3.62^{abc}	3.53^{bcd}	2.13^{a}	2.2^{ab}	2.17^{a}
T_9	3.58^{a}	3.73^{ab}	3.66^{ab}	2.09^{ab}	2.3^{a}	2.13^{ab}
T_{10}	3.64^{a}	3.78^{a}	3.71^{a}	1.89^{bcde}	2.1^{abc}	1.97^{abcdef}
T_{11}	3.34^{c}	3.53^{c}	3.44^{d}	1.83^{de}	1.98^{bcd}	$1.89^{c\ ef}$
T_{12}	3.16^{d}	3.3^{d}	3.23^{e}	1.71^{e}	1.82^{d}	1.76^{f}
Mean	3.30	3.45	3.37	1.93	2.03	1.98
F test	*	*	*	*	*	*
SEm±	0.04	0.057	0.045	0.065	0.069	0.064
CD @ 5%	0.12	0.17	0.13	0.19	0.20	0.18
CV (%)	2.14	2.85	2.34	5.84	5.95	5.59

'*': Significant

T1- Control (RDF 400: 160: 150 g NPK/plant)
T2- Water soluble normal fertilizers foliar spray (NPK fertilizer)
T3- 25% RDF (100: 40: 37 g NPK/plant) + 0.1% Nano NPK fertilizer foliar spray
T4- 25% RDF + 0.2% Nano NPK fertilizer foliar spray
T5- 25% RDF + 0.3% Nano NPK fertilizer foliar spray
T6- 25% RDF + 0.4% Nano NPK fertilizer foliar spray
T7- 25% RDF + 0.5% Nano NPK fertilizer foliar spray
T8- 50% RDF (200: 80: 75 g NPK/plant) + 0.1% Nano NPK fertilizer foliar spray
T9- 50% RDF + 0.2% Nano NPK fertilizer foliar spray
T10-50% RDF + 0.3% Nano NPK fertilizer foliar spray
T11-50% RDF + 0.4% Nano NPK fertilizer foliar spray
T12-50% RDF + 0.5% Nano NPK fertilizer foliar spray

of RDF during both the years 2020-21 and 2021-2022 as well as pooled data is presented in Table 2.

During the year 2020-2021, among all the treatments T_{10} consists of 50% Recommended Dose of Fertilizer (RDF) with foliar application of 0.3% of nano NPK fertilizer was recorded significantly maximum plant spread at East-West and North-South direction (8.26 m and 8.24 m, respectively) while, minimum plant spread at East-West and North-South direction was recorded in treatment T_1 (7.38 m and 7.47 m, respectively).

Similarly, in the year 2021-2022, significantly maximum plant spread at East-West and North-South direction was recorded in treatment T_{10} (9.40 m and 8.71 m, respectively). While minimum plan spread at East-West and North-South direction was recorded in treatment T_1(7.59 m and 7.77 m, respectively).

From the analysed pooled data indicates that significantly maximum plant spread at East-West and North-South direction was recorded in treatment T_{10}(8.83 m and 8.48 m, respectively) and minimum plan spread at East-West and North-South direction was recorded in treatment T_1(7.49 m and 7.62 m, respectively).

Quality parameters

Total Soluble Solids (TSS)

Foliar application of different concentrations of nano-fertilizer along with varied per cent of RDF had significant influence on TSS of sapota fruits during both the years 2020-21 and 2021-2022 as well as pooled data (Table 3).

During the year 2020-2021, the maximum TSS of sapota fruit was recorded in the treatment T_8(21.33^{o}Brix) and during the year 2021-2022, the maximum TSS of sapota fruit was observed in T_9(22.33 ^{o}Brix). While, the least TSS of fruit was observed during both the years (2020-2021 and 2021-2022) in treatment $T_1$15.33^{o}Brix and 17.33 ^{o}Brix respectively. It was evident from the pooled data that the maximum value was recorded in treatment T_9(21.00 ^{o}Brix) and TSS of sapota fruit was observed

Table 2. Effect of nano NPK fertilizer on plant spread (E-W and N-S directions) of sapota tree

Treatments	Plant spread (m)					
	E-W			N-S		
	2021	2022	Pooled	2021	2022	Pooled
T_1	7.38^{j}	7.59^{k}	7.49^{j}	7.47^{i}	7.77^{i}	7.62^{i}
T_2	7.47^{i}	7.67^{j}	7.57^{i}	7.67^{h}	7.97^{h}	7.82^{h}
T_3	7.77^{h}	8.06^{i}	7.91^{h}	7.77^{g}	8.07^{g}	7.92^{g}
T_4	7.87^{g}	8.17^{h}	8.02^{g}	7.68^{h}	8.05^{g}	7.93^{g}
T_5	7.92^{f}	8.22^{g}	8.07^{f}	7.87^{f}	8.17^{f}	8.02^{f}
T_6	8.02^{d}	8.25^{fg}	8.13^{e}	7.92^{e}	8.24^{e}	8.09^{e}
T_7	7.97^{e}	8.27^{ef}	8.12^{e}	8.03^{d}	8.32^{d}	8.17^{d}
T_8	8.08^{c}	9.08^{c}	8.58^{c}	8.08^{cd}	8.31^{d}	8.19^{cd}
T_9	8.24^{a}	9.3^{b}	8.77^{b}	8.17^{b}	8.47^{c}	8.32^{b}
T_{10}	8.26^{a}	9.4^{a}	8.83^{a}	8.24^{a}	8.71^{a}	8.48^{a}
T_{11}	8.12^{b}	8.32^{d}	8.22^{d}	8.12^{c}	8.52^{b}	8.32^{b}
T_{12}	8.1^{bc}	8.3^{de}	8.2^{d}	8.03^{d}	8.43^{c}	8.23^{c}
Mean	7.93	8.38	8.16	7.92	8.25	8.09
F test	*	*	*	*	*	*
SEm±	0.013	0.012	0.008	0.017	0.014	0.007
CD @ 5%	0.037	0.035	0.024	0.050	0.040	0.020
CV (%)	0.278	0.248	0.173	0.370	0.287	0.146

*: Significant

T1- Control (RDF 400: 160: 150 g NPK/plant)
T2- Water soluble normal fertilizers foliar spray (NPK fertilizer)
T3- 25% RDF (100: 40: 37 g NPK/plant) + 0.1% Nano NPK fertilizer foliar spray
T4- 25% RDF + 0.2% Nano NPK fertilizer foliar spray
T5- 25% RDF + 0.3% Nano NPK fertilizer foliar spray
T6- 25% RDF + 0.4% Nano NPK fertilizer foliar spray
T7- 25% RDF + 0.5% Nano NPK fertilizer foliar spray
T8- 50% RDF (200: 80: 75 g NPK/plant) + 0.1% Nano NPK fertilizer foliar spray
T9- 50% RDF + 0.2% Nano NPK fertilizer foliar spray
T10- 50% RDF + 0.3% Nano NPK fertilizer foliar spray
T11- 50% RDF + 0.4% Nano NPK fertilizer foliar spray
T12- 50% RDF + 0.5% Nano NPK fertilizer foliar spray

least in treatment T_1(18.00 °Brix).

Titratable acidity

The acidity (%) of sapota fruit as influenced by foliar application of different concentrations of nano-fertilizer at different intervals along with varied per cent of RDF during both the years 2020-2021 and 2021-2022 as well as pooled data (Table 3).

During both the years (2021-2022 and 2021-2022), the minimum acidity of fruit was recorded in T_9(0.16 %) and maximum acidity of fruit was recorded in treatment T_1(0.24 % and 0.23 %, respectively). From the pooled data it was indicated that significantly minimum acidity of fruit was recorded in T_9(0.16 %) and the maximum acidity (0.24 %) of fruit was recorded in T_1 (Only RDF).

Reducing sugar, Non-reducing sugar and Total sugars

The reducing sugar and total sugars of sapota fruit as influenced by different concentrations of nano-fertilizer along with varied per cent of RDF, recorded significant values among the treatments during both the years 2020-21 and 2021-2022 as well as pooled data is presented in Table 4. However, with respect to non-reducing sugar, it was non-significant among the treatments.

During the year 2020-2021, the maximum values for reducing sugar and total sugars was recorded in the treatment T_8(9.20 % and 21.88 %, respectively) and least values for reducing and total sugars was observed in T_1(7.17 % and 17.21 %, respectively). Similarly in the year 2021-2022, the maximum values for reducing and total sugars was observed in T_9(9.31 % and 22.18 % respectively) and least value for reducing and total sugars was observed in treatment T_1(7.40 % and 17.37 %, respectively). From the pooled data result indicated that, the maximum values for reducing and total sugars was recorded in treatment T_8(9.24 % and 22.02 % respectively) and reducing and total sugars were observed least in treatment T_1(7.29 % and 17.29 %, respectively).

Shelf life of fruit at room temperature

The effect of nano NPK fertilizer along with varied per cent of RDF was found significant with respect to shelf life of sapota fruits at room temperature

Table 3. Effect of nano NPK fertilizer on TSS and titratable acidity of sapota fruit

Treatments	TSS (°Brix)			Titratable acidity (%)		
	2021	2022	Pooled	2021	2022	Pooled
T_1	15.33^{c}	17.33^{e}	18^{cde}	0.24^{a}	0.23^{ab}	0.24^{a}
T_2	15.67^{c}	17.67^{de}	17.5^{de}	0.2^{bc}	0.23^{a}	0.22^{b}
T_3	17.33^{bc}	19^{cde}	18.5^{bcde}	0.19^{cd}	0.23^{ab}	0.21^{bc}
T_4	18^{bc}	19.67^{bcd}	18.83^{bcd}	0.21^{b}	0.21$^{a\ cd}$	0.21^{bc}
T_5	21.33^{a}	21.67^{ab}	19.67^{abc}	0.2^{bc}	0.21$^{a\ cd}$	0.2^{bc}
T_6	18^{bc}	19.67^{bcd}	18.83^{bcd}	0.21^{b}	0.2^{de}	0.21^{bc}
T_7	17.67^{bc}	19.33^{cde}	18.5^{bcde}	0.2^{bc}	0.19^{e}	0.2^{bc}
T_8	21.33^{a}	21.67^{ab}	19.83^{ab}	0.17^{ef}	0.17^{f}	0.17^{d}
T_9	21.33^{a}	22.33^{a}	21^{a}	0.16^{f}	0.16^{f}	0.16^{d}
T_{10}	17.67^{bc}	19.67^{bcd}	18.17^{bcde}	0.18^{de}	0.2^{de}	0.19^{c}
T_{11}	16.67^{bc}	18.67^{cde}	17^{e}	0.2^{bc}	0.22^{abc}	0.21^{bc}
T_{12}	18.33^{b}	20.33^{abc}	18.67^{bcde}	0.21^{b}	0.22^{abc}	0.22^{b}
Mean	18.08	19.69	18.13	0.20	0.21	0.20
F test	*	*	*	*	*	*
SEm±	0.79	0.65	0.50	0.0059	0.0060	0.0045
CD @ 5%	2.32	1.92	1.47	0.017	0.018	0.013
CV (%)	7.59	5.75	4.79	5.22	5.10	3.92

*: Significant NS: Non-significant

T1- Control (RDF 400: 160: 150 g NPK/plant)
T2- Water soluble normal fertilizers foliar spray (NPK fertilizer)
T3- 25% RDF (100: 40: 37 g NPK/plant) + 0.1% Nano NPK fertilizer foliar spray
T4- 25% RDF + 0.2% Nano NPK fertilizer foliar spray
T5- 25% RDF + 0.3% Nano NPK fertilizer foliar spray
T6- 25% RDF + 0.4% Nano NPK fertilizer foliar spray
T7- 25% RDF + 0.5% Nano NPK fertilizer foliar spray
T8- 50% RDF (200: 80: 75 g NPK/plant) + 0.1% Nano NPK fertilizer foliar spray
T9- 50% RDF + 0.2% Nano NPK fertilizer foliar spray
T10- 50% RDF + 0.3% Nano NPK fertilizer foliar spray
T11- 50% RDF + 0.4% Nano NPK fertilizer foliar spray
T12- 50% RDF + 0.5% Nano NPK fertilizer foliar spray

during both the years (2020-2021 and 2021-22) as well as pooled data (Table 5).

During both the years(2020-21 and 2021-2022) as well as pooled data, shelf life of the fruits enhanced significantly, the maximum shelf life was recorded in T_9 (6.67 days, 7.00 days and 6.83 days respectively), which was followed by treatment T_8(6.00 days, 6.33 days and 6.17 days).The minimum shelf life of fruit was recorded in treatment T_1(4.33 days, 4.67 days and 4.50 days).

Fruit firmness

The firmness of sapota fruit as influenced by foliar application of different concentrations of nano-fertilizer at different intervals along with varied per cent of RDF during both the years 2020-21 and 2021-22 as well as pooled data (Table 5).

During both the years (2020-2021 and 2021-2022) as well as pooled data, the maximum value for firmness of sapota fruit was recorded in the treatment T_9(71.02 N, 74.00 N and 72.51 N respectively) and less value for firmness of sapota fruit was observed in treatment T_1(64.02 N, 67.17 N and 65.59 N respectively).

Discussion

Growth parameters

Maximum plant height was obtained might be due to the fact that nano-fertilizer has unique properties due to its more surface area with high absorption capacity attributed to better nutritional environment in the plant system. Nitrogen, phosphorus and potassium are most indispensable of all mineral nutrients for growth and development of the plant as these are the basis of fundamental constituents of all living matter, these properties of nano-fertilizer causes an increase in photosynthesis and increased leaf area there by it might have increased the plant height (Sekhon, 2014). The results are in line with the findings of Sabir *et al*. (2014) in blueberries, Roshdy and Refai (2016) in date palm and Mohasedat *et al.* (2018) in apple. Increased leaf chlorophyll content might be due to use of foliar spray of nano formulations which might have enhanced the availability of nutrients by easy penetration through stomata of leaves via gas exchange. Application of nano-fertilizers intensify the function of manganese in the process of photosynthesis, which turns the light of the sun into plant energy, which affected the formation of green plastids in the leaves and the production of chlorophyll in the leaves. Especially nitrogen fertilizer activates the enzymes associated with chlorophyll formation, hence it might have increased the chlorophyll content in the leaves. The similar observations were made by Roshdy and Refai (2016) in date palm, Sabir *et al.* (2014) in grapes and Abdelaziz *et al*. (2019) in mango.

Table 4. Effect of nano NPK fertilizer on reducing sugar, non-reducing sugar and total sugars of sapota fruit

Treatments	Reducing sugar (%)			Non-reducing sugar (%)			Total sugar (%)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1	7.17^{e}	7.4^{d}	7.29^{d}	9.39	10.21	9.80	17.21^{ef}	17.37^{a}	17.29^{de}
T_2	8^{bcd}	8.2^{bc}	8.1^{bc}	12.24	10.20	11.22	18.07^{cdef}	18.4^{a}	18.23^{bcde}
T_3	7.82^{cd}	8.02^{bc}	7.92^{bc}	12.74	11.28	12.01	19.01^{cd}	19.3^{a}	19.16^{bc}
T_4	8.04^{bc}	8.22^{bc}	8.13^{bc}	12.84	10.29	11.56	19.43^{bc}	19.6^{a}	19.52^{b}
T_5	8.93^{a}	9.07^{a}	9^{a}	14.60	13.11	13.86	18.4^{cde}	18.92^{a}	18.66^{bcd}
T_6	5.9^{f}	6.06^{e}	5.98^{e}	11.42	10.88	11.15	16.57^{f}	16.93^{a}	16.75^{e}
T_7	9.04^{a}	9.2^{a}	9.12^{a}	12.52	9.95	11.24	18.7^{cde}	19.15^{a}	18.93^{bcd}
T_8	9.2^{a}	9.28^{a}	9.24^{a}	14.75	12.87	13.81	21.88^{a}	22.16^{a}	22.02^{a}
T_9	9.16^{a}	9.31^{a}	9.24^{a}	12.04	10.69	11.37	21.72^{a}	22.18^{a}	21.95^{a}
T_{10}	8.26^{b}	8.4^{b}	8.33^{b}	13.75	12.80	13.28	20.9^{ab}	21.19^{a}	21.05^{a}
T_{11}	7.62^{d}	7.82^{c}	7.72^{c}	11.65	9.85	10.75	17.44^{def}	17.67^{a}	17.56^{cde}
T_{12}	8.07^{bc}	8.13^{bc}	8.1^{bc}	11.46	9.97	10.71	18.08^{cdef}	18.34^{a}	18.21^{bcde}
Mean	8.10	8.26	8.18	12.45	11.01	11.73	18.95	19.27	19.11
F test	*	*	*	NS	NS	NS	*	*	*
SEm±	0.13	0.14	0.13	9.72	0.46	8.81	0.51	0.53	0.51
CD @ 5%	0.39	0.43	0.40	28.52	1.37	25.81	1.50	1.56	1.51
CV (%)	2.86	3.05	2.94	135.28	7.37	129.98	4.64	4.79	4.67

*: Significant NS: Non-significant

Table 5. Effect of nano NPK fertilizer on shelf life of sapota fruits and firmness of sapota fruits

Treatments	Shelf life (Days)			Firmness (N)		
	2021	2022	Pooled	2021	2022	Pooled
T_1	4.33^{c}	4.67^{c}	4.5^{d}	64.02^{h}	67.17^{j}	65.59^{h}
T_2	5^{bc}	5^{c}	5^{cd}	65.16^{efg}	67.67^{i}	66.41^{g}
T_3	5^{bc}	5.33^{bc}	5.17^{cd}	65.5^{efg}	68.17^{h}	66.83^{fg}
T_4	4.67^{bc}	5^{c}	5^{cd}	65.62^{efg}	69^{g}	67.31^{ef}
T_5	5^{bc}	5.33^{bc}	5.17^{cd}	66.17^{de}	69.33^{f}	67.75^{e}
T_6	5.33^{abc}	4.67^{c}	5^{cd}	66.69^{d}	70.19^{e}	68.44^{d}
T_7	5.67^{abc}	5^{c}	5.33^{cd}	68.9^{c}	71.08^{d}	69.99^{c}
T_8	6^{ab}	6.33^{ab}	6.17^{ab}	69.97^{b}	72.17^{c}	71.07^{b}
T_9	6.67^{a}	7^{a}	6.83^{a}	71.02^{a}	74^{a}	72.51^{a}
T_{10}	5.67^{abc}	5.67^{bc}	5.67^{bc}	66^{def}	73.17^{b}	69.58^{c}
T_{11}	4.67^{bc}	5.33^{bc}	5^{cd}	65^{fgh}	70^{e}	67.5^{e}
T_{12}	4.67^{bc}	5^{c}	4.83^{cd}	64.67^{gh}	69^{g}	66.83^{fg}
Mean	5.25	5.36	5.31	66.56	70.08	68.32
F test	*	*	*	*	*	*
SEm±	0.44	0.37	0.26	0.32	0.10	0.17
CD @ 5%	1.28	1.10	0.76	0.95	0.31	0.49
CV (%)	14.50	12.11	8.51	0.84	0.26	0.43

*: Significant NS: Non-significant

T1- Control (RDF 400: 160: 150 g NPK/plant)
T2- Water soluble normal fertilizers foliar spray (NPK fertilizer)
T3- 25% RDF (100: 40: 37 g NPK/plant) + 0.1% Nano NPK fertilizer foliar spray
T4- 25% RDF + 0.2% Nano NPK fertilizer foliar spray
T5- 25% RDF + 0.3% Nano NPK fertilizer foliar spray
T6- 25% RDF + 0.4% Nano NPK fertilizer foliar spray
T7- 25% RDF + 0.5% Nano NPK fertilizer foliar spray
T8- 50% RDF (200: 80: 75 g NPK/plant) + 0.1% Nano NPK fertilizer foliar spray
T9- 50% RDF + 0.2% Nano NPK fertilizer foliar spray
T10- 50% RDF + 0.3% Nano NPK fertilizer foliar spray
T11- 50% RDF + 0.4% Nano NPK fertilizer foliar spray
T12- 50% RDF + 0.5% Nano NPK fertilizer foliar spray

The influence of nano-fertilizers on enhancing the growth of the tree was more pronounced rather than straight fertilizers. These nano-fertilizers are readily available to the plants and imparts increasing in plant spread. This might be due to the increased amount of nutrients such as nitrogen, phosphorus and potassium in plants led to increase in the anabolism of plant metabolites that build the plant tissues. These results are similar with the findings of Roshdy and Refai (2016) in date palm and Mohasedat *et al.* (2018) in apple.

Quality parameters

Increased TSS of fruit may be due to nano-fertilizers application, as these nanoparticles have unique in behavior and characteristics, such as small size, targeted delivery of nutrients and highly active area, which increased the rapidity of fruit chemical reactions and also would have activated many enzymes involved in the biochemical pathways such as carbohydrate metabolism and protein. These results are in line with Davarpanah *et al.* (2016) in pomegranate, Roshdy and Refaai (2016) in date palm and Mohamed Gad *et al.* (2021) in mango.The decreased level of acidity was observed in nano-fertilizers sprayed fruits might be due to these nano-fertilizers absorbed easily by plant and translocated into the different parts of the plants especially the potassium application resulted in reduced acid content of the fruits. These results are similar with the findings of Abdelaziz *et al.* (2019) in mango.

There was increased reducing and total sugars content in the fruit might be due to the fact that important regulatory effect of nano fertilizers in activating metabolic enzymes, biosynthesis and translocation of sugars, water absorption and nutrient transport which might have increased the sugar level in the fruit. More reducing sugar in the treatments might be due to especially N as it plays an important role in transformation of organic acids to sugars. These results are in consistent with Abdelaziz *et al.* (2019) in almond, Wassel *et al.* (2017) in grape and Mosa *et al.* (2021) in peach.

Application of nano-fertilizers through foliar spray resulted in easy nutrients penetration into plant tissue and makes availability of nutrients

throughout plant growth period which has produced more reserved food material (carbohydrates) in fruits. High carbohydrate accumulation was responsible for increasing the shelf-life of fruit. It might be the important factor for the positive effects of nutrition in enhancing the shelf life of fruits. Also observed that the nitrogen is an essential constituent of various proteins and play an active part in various metabolic processes which might have played a role in augmenting the shelf life of fruits. Similar research reported by Li. *et al.* (2011) in apple and Wassel *et al.* (2017) in grapes.

Conclusion

On the basis of the present investigation it may be concluded that 50 per cent of RDF with foliar application of 0.3 per cent nano NPK fertilizer and 50 per cent of RDF with foliar application of 0.2 per cent of nano NPK fertilizer were proved significant for improved plant growth and fruit quality of sapota when compared with other treatments especially with respect to obtaining maximum plant height, plant spread, chlorophyll content and quality attributes (TSS of fruit, Reducing, total sugars, shelf life of fruits and fruit firmness). Data indicated that application of nano fertilizers resulted in reduced the use of amount inorganic fertilizers.

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