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Effect of combined application of nutrients on fruit quality of sapota (*Acharas zapota*) cv. Kalipatti

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ABSTRACT

Indiscriminate use of inorganic fertilisers is a threat to environment coupled with adverse effects on quality of produce and soil health. Integrated nutrient management (INM) can fulfill the nutrients need of the sapota (*Acharas zapota* L.) plants for qualitative and quantitative produce and reduce the need of chemical fertilisers. The current study was performed to appraise the impact of chemical, organic and biological fertilisers on quality production of sapota at ICAR-Indian Institute of Soil and Water Conservation, Kota, Rajasthan during 2020–21 and 2021–22. The study included 17 different treatment combinations, including farm yard manure (FYM), vermicompost, recommended dose of fertilisers (RDF) and biofertilisers. The findings of conducted field trial reported that integration of RDF 75% + VC 10 kg + AZS 250 g + AZB 250 g/plant recorded higher fruit diameter (5.67 cm), length of fruit (6.20 cm) and weight of fruit (100.17 g). Beside this, higher fruit firmness (4.96 kg/cm^2) and pulp:seed ratio (93.09) were recorded in the same treatment. Although, biochemical parameters for instance total soluble solids (20.05°B), ascorbic acid (11.86 mg/100 g pulp), TSS:acid ratio (121.29) and reducing sugar (5.11%) were recorded in treatment having RDF 75% + FYM 50 kg + AZS 250 g + AZB 250 g/plant. The impact demonstrated that applying two-thirds of the recommended quantity of inorganic fertilisers i.e. 1000 g, 500 g and 500 g NPK/plant in sapota cv. Kalipatti enhanced total soluble solids (TSS) content (9.68%) and fruit weight (13.72 %) over the control.

Keywords: Biochemical parameters, Biofertilisers, Organic matter, Organoleptic acceptance, Soil health

Sapota (*Acharas zapota* L.) is a well-known fruit in the Sapotaceae family. Sapota has originated from Mexico and Central America and is extensively grown for its mouth-watering fruits across the tropics (Bose and Mitra 1990). India stands first position in sapota fruit production over the world. It is estimated that sapota grown in around 97 thousand hectares area with 11.7 lakh tonnes fruit production in India (NHB 2018).

Sapota is mainly consumed as fresh fruit and also used in the form of osmodehydrated slices, jams, jellies and squash (Reddy 1959). White sticky latex is used to make chicle which is utilised in chewing gum preparation (Ravindran *et al.* 2007). Kalipatti is the leading variety of Maharashtra, Gujarat and northern Karnataka (Chundawat and Bhuva 1982) having dark green leaves, spreading habit and oval fruit of outstanding quality. The fruit is fleshy berry, variable in shape, size and weight (75–150 g) with 1–2 seeds/fruit. The skin is thin, rusty brown somewhat scurfy looking like Iris potato and the pulp soft, melting, crumbling with a sandy or granular texture. Immature fruits are astringent, while ripe fruits are sweet and tasty.

In Indian fruit orchards, poor soil health and imbalanced nutrient application are major causes of low orchard efficiency resulting in poor quality production (Hebbara *et al.* 2006, Somasundaram *et al.* 2011, Meena *et al.* 2019). However, proper nutrition of sapota orchards is very essential and crucial in order to boost up the growth and quality production of plants but limited work has been done on this aspect. Thus, the study was carried out to analyse integrated nutrient management (INM) through combination of organic, inorganic and biofertilisers in sapota. INM can supplement the requirement of the plant nutrients for quantitative as well as qualitative production. Organic sources of nutrients are known to improve fruit quality and soil health by increasing the rhizosphere micro flora.

MATERIALS AND METHODS

Study site: The current study was carried out during 2020–21 and 2021–22 at ICAR-Indian Institute of Soil and Water Conservation, (25º 11' N, 75º 51' E; at an elevation of

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Table 1 Basic information of soil nutrient status of the experimental site

Mechanical					Physical	Chemical				
Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Textural class	Bulk density (g/cc)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Organic Carbon (%)	Electrical conductivity (dS/m at 25ºC)
3.79	54.0	17.7	34.5	Clay loam	1.35	273.26	12.43	595.54	0.45	0.42

256.9 m amsl), Rajasthan on sapota cv. Kalipatti. The clay loam soil at the research trial location has an approximate *p*H of 7.6, EC of 0.42 dS/m, and 0.45% organic carbon. Nitrogen, phosphorous, and potash nutrients were available in the amounts of 273, 12.43, and 595 kg/ha, respectively. The basic information of soil nutrient status of the experimental location has shown in Table 1.

Planting material and treatment details: Sapota cv. Kalipatti plantation was established at a distance of 8 m × 8 m. Experiment was performed on 14-years old sapota plants with 17 treatment combinations, viz. T_0, RDF (Recommended dose of fertilisers) @1000:500:500 g NPK/plant; T_1, RDF 50% + FYM 50 kg + Phosphate solublising bacteria (PSB) 250 g/plant; T_2, RDF 50% + FYM 50 kg + *Azo spirillum* (AZS) 250 g + *Azoto bacter* (AZB) 250 g/plant; T_3, RDF 50% + FYM 50 kg + PSB 250 g + AZS 250 g/plant; T_4, RDF 50% + FYM 50 kg + AZB 250 g/plant; T_5, RDF 50% + VC 10 kg + PSB 250 g/plant; T_6, RDF 50% + Vermicompost (VC) 10 kg + AZS 250 g + AZB 250 g/plant; T_7, RDF 50% + VC 10 kg + PSB 250 g + AZS 250 g/plant; T_8, RDF 50% + VC 10 kg + AZB 250 g/plant; T_9, RDF 75% + FYM 50 kg + PSB 250 g/plant; T_{10}, RDF 75% + FYM 50 kg + AZS 250 g + AZB 250 g/plant; T_{11}, RDF 75% + FYM 50 kg + PSB 250 g + AZS 250 g/plant; T_{12}, RDF 75% + FYM 50 kg + AZB 250 g/plant; T_{13}, RDF 75% + VC 10 kg + PSB 250 g/plant; T_{14}, RDF 75% + VC 10 kg + AZS 250 g + AZB 250 g/plant; T_{15}, RDF 75% + VC 10 kg + PSB 250 g + AZS 250 g/plant; T_{16}, RDF 75% + VC 10 kg + AZS 250 g/plant. Four plants were selected as treatment units. The experimentation was formulated in randomised block design (RBD) with four replications. Full amount of phosphorus, potash and half dose of nitrogen in various treatments were applied as basal dose before vegetative sprouting in the month of June. Remaining half dose of nitrogen was applied after fruit set in the month of December. The FYM, vermicompost and biofertilisers were applied before onset of monsoon (June). Fertilisers were applied in a ring which covers an area of 90 cm away periphery of the plant trunk and covering the periphery of the plants.

The results on the parameters associated with fruit quality were recorded following the 120-day application of the fertilisers.

Analysis of physical parameters of fruits: The physical assessment of fruit included measurements for fruit weight, diameter and length. Using a vernier caliper, the length and diameter of fruit recorded at harvest in cm. Digital balance was used to record average fruit weight. To calculate individual fruit weight, total weight of fruits was divided by total number of fruits and presented in g.

Analysis of biochemical parameters of fruits: Fruit was chemically examined to determine its TSS (Total soluble solids), TSS: Acid ratio, reducing sugar, total sugars, acidity and ascorbic acid. TSS of the fruits pulp was measured with digital refractometer, which has a range of 0–32°B. Fruit acidity was determined by the titration method of acid-alkaline (AOAC 1990). Ascorbic acid component of sapota fruit pulp was analysed according to Ranganna (1986). The ratio of TSS-acidity was measured by dividing total soluble solid content by the acidity. The reducing sugar of fruit pulp was analysed by Nelson's modifications of Somogyi's method (Somogyi 1952).

Analysis of quality characteristics of fruit: Fruit quality was determined by factors such as fruit firmness, pulp:seed ratio, and organoleptic acceptability. The sapota fruits firmness was measured by texture analyser with a 2 mm diameter SS probe. Pulp to seed ratio of fruit was determined by dividing the weight of individual fruit pulp by weight of individual fruit seeds. A panel of seven judges evaluated the organoleptic acceptability of sapota fruits from each treatment after three days of storage in ambient conditions in corrugated fibre board boxes with hedonic scale of 9.0 points (Amerine *et al.* 1965). The rating was assigned to the observations based on the fruit colour, taste and the appearance i.e. 9.0, Incredibly accepted; 8.0, Accepted too much; 7.0, Accepted quietly; 6.0, Accepted a little; 5.0, Neither accepted nor refused; 4.0, Refused slightly; 3.0, Refused quietly; 2.0, Refused too much; and 1.0, Refused incredibly. The final scoring was done by averaging the marks obtained and the rating "accepted quietly" was taken into account for the acceptability of the fruits.

Statistical analysis: Collected research data of the experiment were analysed using one-way analysis of variance with the help of Duncan test, $\alpha = 0.05$, using statistical program Statistica (Ver. 13.1, 2017). The analysed data which were not significantly different from each other are mentioned with same small letters.

RESULTS AND DISCUSSION

Effect of INM on sapota fruit diameter, length and weight: Results demonstrated the considerable effect of various combination of organic, inorganic, and biofertiliser applications on diameter, length and weight of fruit

Table 2 Effect of INM treatments on diameter of fruit, length of fruit and weight of fruit in sapota cv. Kalipatti (pooled data of two years)

Treatments	Diameter of fruit (cm)	Length of fruit (cm)	Weight of fruit (g)
T_0 (control)	4.61^{a}	5.39^{abc}	88.08^{cd}
T_1	4.44^{a}	5.26^{a}	62.28^{a}
T_2	5.39^{bcd}	5.94^{fg}	63.95^{a}
T_3	5.37^{bcd}	5.84^{cdefg}	64.69^{a}
T_4,	4.87^{abc}	5.43^{abcd}	80.90^{bc}
T_5	4.96^{abc}	5.45^{abcd}	82.38^{bcd}
T_6	5.32^{bcd}	5.87^{defg}	78.82^{b}
T_7	5.44^{bcd}	5.92^{efg}	90.02^{de}
T_8	4.99^{abc}	5.46^{abcde}	80.00^{bc}
T_9	5.24^{bcd}	5.68^{abcdef}	83.20^{bcd}
T_{10}	5.64^{d}	6.04^{fg}	97.50^{ef}
T_{11}	5.49^{cd}	6.03^{fg}	90.39^{de}
T_{12}	4.59^{a}	5.35^{ab}	79.31^{bc}
T_{13}	5.27^{bcd}	5.69^{abcdef}	82.12^{bcd}
T_{14}	5.67^{d}	6.20^{g}	100.17^{f}
T_{15}	5.28^{bcd}	5.73^{bcdefg}	83.91^{bcd}
T_{16}	4.85^{ab}	5.42^{abcd}	85.26^{bcd}

Different small letters indicate a significant difference between all the treatments ($p<0.05$). Treatment details are given under Materials and Methods.

(Table 2). The treatment T_{14} being at par with T_2, T_3, T_6, T_7, T_9, T_{10}, T_{11}, T_{13} and T_{15} gave highest fruit diameter (5.67 cm) and showed 27.7 % superiority over T_1 which gave least fruit diameter (4.44 cm) while treatment T_{14} exhibited maximum fruit length (6.20 cm) which was 17.87% higher than T_1. Further, the application of T_2, T_3, T_6, T_7, T_{10} and T_{11} treatments were statistically at par to the treatment T_{14}. The maximum fruit weight (100.17 g) also was recorded at T_{14} treatment, followed by treatment T_{10} (97.50 g) and minimum fruit weight (62.28 g) was recorded at T_1 treatment. However, the treatments T_7, T_{10}, T_{11} and T_{14} were found to be statistically at par among each other.

The results clearly demonstrated that increased synthesis of growth-promoting chemicals including indole acetic acid, gibberellic acid and dihydrozeatin has been produced as a result of the synergistic interaction between inorganic fertilisers, organic manures, and biofertilisers. They have a favourable effect on the physiological activity of the plants, which improves the diameter and length of the fruit and, in turn, raises its average weight. Additionally, they are known to produce vitamins, acids, and growth-promoting compounds such as GA_3, IAA, etc. which may aid in increasing the size of fruits (Kashyap *et al.* 2004). These findings are in compliance with the previous research work of Sheik *et al.* (2019) and Kumar *et al.* (2020) in sapota, Ashok *et al.* (2024) in acid lime and Gondaliya *et al.* (2025) in custard apple.

Effect of INM on TSS, acidity and ascorbic acid: The data showed that the soil application of T_{10} gave highest total soluble solid (20.05°B) in sapota pulp. Whereas, the minimum value of total soluble solid was noticed in T_1 treatment (18.10°B). Treatment T_{10} enhanced TSS content of sapota pulp by 9.68% over T_0 treatment. Treatments T_6, T_9, T_{10}, T_{11} and T_{14} were found to be statistically at par among each other (Table 3). An increase in the TSS of fruits may have improved fruit quality by aiding with the process of photosynthesis, which in turn produced a significant amount of carbohydrates and an increase in the TSS content of sapota fruits (Prasad *et al.* 2010). This enhancement in TSS content resulted in decreased acidity of fruits. The treatment T_{10} (0.166%) followed by T_{11} (0.174%) produced the fruits with the lowest percent of acidity, which is a desired parameter in assessing fruit quality. However, maximum acidity per cent was noticed in treatment T_1 (0.196). We also observed that decrease in fruit acidity of 18.1% under T_{10} treatment compared to T_1 treatment. With the addition of nutrients, the acidity of sapota fruits was considerably reduced. This might be due to balanced

Table 3 Effect of INM treatments on total soluble solids, acidity and ascorbic acid in sapota fruit cv. Kalipatti (pooled data of two years)

Treatments	TSS (°B)	Acidity (%)	Ascorbic acid (mg/100 g pulp)
T_0 (control)	18.28^{ab}	0.185^{cd}	10.37^{ab}
T_1	18.10^{a}	0.196^{e}	10.22^{a}
T_2	18.31^{ab}	0.177^{bcd}	10.42^{ab}
T_3	18.47^{abc}	0.186^{de}	10.38^{ab}
T_4	18.96^{bcd}	0.177^{bcd}	11.66^{de}
T_5	18.77^{abcd}	0.176^{bcd}	11.27^{cd}
T_6	19.08^{bcde}	0.176^{abc}	10.47^{ab}
T_7	18.55^{abc}	0.176^{abc}	10.56^{ab}
T_8	18.62^{abc}	0.176^{abc}	10.83^{bc}
T_9	19.17^{cde}	0.176^{bcd}	10.78^{abc}
T_{10}	20.05^{f}	0.166^{a}	11.86^{e}
T_{11}	19.55^{def}	0.174^{abc}	11.68^{de}
T_{12}	18.52^{abc}	0.176^{bcd}	11.24^{cd}
T_{13}	18.81^{abcd}	0.176^{bcd}	11.65^{de}
T_{14}	19.82^{ef}	0.175^{abc}	11.72^{de}
T_{15}	18.87^{abcd}	0.176^{ab}	10.49^{ab}
T_{16}	19.24^{cde}	0.176^{bcd}	10.82^{abc}

Different small letters indicate a significant difference between all the treatments ($p<0.05$). Treatment details are given under Materials and Methods.

application of nutrients along with organic manures might have increased sugar content in sapota.

The soil application of T_{10} recorded considerably higher ascorbic acid (11.86 mg/100 g pulp), followed by T_{14} (11.72 mg/100 g pulp) as compared to lower in treatment T_1. Although, the treatment T_4, T_{11}, T_{13} and T_{15} were noticed statistically at par with T_{10}. The increment in ascorbic acid content was registered more (16.04%) under T_{10} than T_1 treatment and 14.36% higher than T_0. Integration of chemical, organic, and biological fertilisers to the soils not only serves as a complete repository for macro and micronutrients but also has positive influence on different soil properties (Prasad *et al.* 2010). This enhancement in TSS content resulted in decreased acidity of fruits. The results of this study are in trend of Wahid *et al.* (1991) who noted that application of N_2 enhanced the fruits quality by enhancing the total soluble solid, sugar, ascorbic acid and decreased the acidity level in sapota fruits. Further, the present results are close to earlier work of Kumar *et al.* (2020) in sapota, Kumari *et al.* (2023) in pomegranate and Ray *et al.* (2024) in mango.

Effect of INM on TSS:acid ratio, reducing sugar and total sugar: It is evident from the data (Table 4) that the maximum TSS/acid ratio (121.29) recorded with treatment T_{10} followed by T_{14} (113.68) and minimum was registered in treatment T_1 (92.41). However, treatment T_{10} recorded higher TSS/acid ratio (22.44%) compared to treatment (T_0). It is apparent from the data that INM had significantly higher TSS/acid ratio in sapota fruit. Pooled data analysis indicated that T_{10} recorded maximum reducing sugar content of 5.11%. This treatment was closely followed by T_{14} treatment. A minimum of 4.34% reducing sugar was observed when T_1 treatment was applied to the soil. However, treatments T_{10}, T_{12}, T_{13}, T_{14} and T_{16} treatments were found statistically at par with each other. This might be because of the higher sugar content, which can be linked to the role of N_2 in a variety of energy sources, including sugars and amino acids. The INM have a considerable impact on total sugars of sapota fruits. The maximum total sugars was noticed for the treatment T_{10} (7.32%) followed by treatment T_{14} (7.12%) and minimum (6.33%) under T_1. However, T_{10} recorded higher total sugar contents of 13.99 and 14.17% higher over the T_0 and T_1 treatments, respectively. These results align with the findings of Sheik *et al.* (2019) in sapota, Kumari *et al.* (2023) in pomegranate, Ray *et al.* (2024) in mango and Gondaliya *et al.* (2025) in custard apple.

Effect of INM on fruit firmness, pulp/seed ratio and organolepic acceptance: All the treatments had a noticeable effect on the firmness of the sapota fruits. However, the pooled data showed that T_{14} treatment exhibited significantly higher fruit firmness (4.96 kg/cm^2) followed by treatment T_{10} (4.93 kg/cm^2). It was statistically at par with T_4, T_7, T_{10}, T_{11} and T_{16} treatments. The minimum fruit firmness was observed at T_1 treatment. The increment in fruit firmness was registered 5.08% more under T_{14} than T_0 (Table 5). This could be the result of slow biochemical changes in the conversion of starch to sugar fraction as well as slower rates of ripening and softening of the pulp composition. The current results are in line with the studies of Patel *et al.* (2017) in sapota.

Table 4 Effect of INM treatments on TSS:acid ratio, reducing sugar and total sugars in sapota fruit cv. Kalipatti (pooled data of two years)

Treatments	TSS/ acid ratio	Reducing sugar (%)	Total sugar (%)
T_0 (control)	99.06^{b}	4.73^{bcdef}	6.43^{a}
T_1	92.41^{a}	4.34^{a}	6.33^{a}
T_2	103.49^{cd}	4.78^{cdefg}	6.53^{a}
T_3	99.50^{bc}	4.70^{abcdef}	6.69^{abc}
T_4	107.19^{de}	4.57^{abcd}	6.81^{abc}
T_5	106.72^{de}	4.63^{abcde}	7.07^{bcd}
T_6	108.55^{ef}	4.80^{cdefg}	6.64^{ab}
T_7	105.39^{de}	4.37^{ab}	6.81^{abc}
T_8	105.85^{de}	4.47^{abc}	6.59^{a}
T_9	109.02^{ef}	4.39^{ab}	6.48^{a}
T_{10}	121.29^{h}	5.11^{g}	7.32^{d}
T_{11}	112.59^{fg}	4.88^{defg}	7.11^{cd}
T_{12}	105.66^{de}	4.90^{defg}	6.45^{a}
T_{13}	107.22^{de}	4.93^{defg}	6.44^{a}
T_{14}	113.68^{g}	5.04^{fg}	7.12^{cd}
T_{15}	107.53^{de}	4.85^{defg}	6.71^{abc}
T_{16}	109.88^{efg}	4.96^{efg}	6.72^{abc}

Different small letters indicate a significant difference between all the treatments ($p<0.05$). Treatment details are given under Materials and Methods.

The pooled analysis indicated that highest pulp:seed ratio (93.09) was recorded in treatment T_{14} and lowest (72.80) in T_1. However, T_{14} treatment registered higher pulp:seed ratio (16.31 and 27.87%) higher over the treatment T_0 and T_1, respectively. The aforementioned outcomes closely support previous findings of Dwivedi *et al.* (2010) in guava. The study findings suggested that the organoleptic score of fruit was significantly impacted by several integrated nutrition management methods. The highest organoleptic score (8.88) was noticed in T_{10} treatment, whereas the lowest score of 5.22 with T_1. However, the increase in organoleptic acceptance score of fruit by application of T_{14} treatment was 27.95% higher over the treatment T_0. Treatments T_{10} and T_{14} were found statistically close at par with each other. The outcomes of the current research findings are parallel to the results of Bavisker *et al.* (2011) in sapota cv. Kalipatti, Kumar and Kaur (2021) in peach cv. Shan-i-Punjab and Kumari *et al.* (2023) in pomegranate.

The study concluded that the T_{10} treatment enhanced

Table 5 Effect of INM treatments on fruit firmness, pulp:seed ratio and organoleptic acceptance of sapota fruit cv. Kalipatti (pooled data of two years)

Treatments	Fruit firmness (kg/cm^2)	Pulp:seed ratio	Organoleptic acceptance
T_0 (control)	4.72^{def}	80.03^{abcd}	6.94^{f}
T_1	4.19^{a}	72.80^{a}	5.22^{a}
T_2	4.25^{ab}	73.97^{ab}	6.07^{de}
T_3	4.27^{abc}	75.25^{abc}	5.58^{b}
T_4	4.65^{bcdef}	76.47^{abc}	5.63^{bc}
T_5	4.41^{abcd}	78.24^{abc}	5.67^{bc}
T_6	4.23^{a}	78.58^{abc}	5.95^{cd}
T_7	4.85^{ef}	77.55^{abc}	5.69^{bc}
T_8	4.35^{abcd}	79.17^{abc}	5.97^{cd}
T_9	4.43^{abcd}	80.08^{abcd}	6.32^{e}
T_{10}	4.93^{f}	90.95^{fg}	8.88^{j}
T_{11}	4.88^{f}	89.99^{efg}	7.82^{h}
T_{12}	4.38^{abcd}	83.97^{cdef}	7.09^{f}
T_{13}	4.36^{abcd}	81.80^{abcde}	7.45^{g}
T_{14}	4.96^{f}	93.09^{g}	8.32^{i}
T_{15}	4.48^{abcde}	83.09^{bcdef}	7.69^{gh}
T_{16}	4.67^{cdef}	88.79^{defg}	7.57^{gh}

Different small letters indicate a significant difference between all the treatments ($p<0.05$). Treatment details are given under Materials and Methods.

the nutritional qualities of sapota fruits, viz. TSS, sugars, TSS:acid ratio, organoleptic acceptance score, improvement in ascorbic acid and reduction in acidity of fruit. Hence, above treatment is economically feasible and viable for sapota cultivation. From the findings, it can be suggested that sapota growers should apply RDF 75% + FYM 50 kg + AZS 250 g + AZB 250 g/plant to obtain optimum yield of quality fruits in sapota orchard at initial bearing stage in agro-climatic zone V (South-Eastern Humid Plain) conditions. Organic and inorganic inputs such as vermicompost, FYM, beneficial microbes, and the proper doses of fertilisers significantly enhance the quality characteristics of sapota crop.

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