E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2025; SP-8(1): 104-109
Received: 11-11-2024
Accepted: 17-12-2024

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Economics of tomato (*Solanum lycopersicum* L.) under sapota (*Manilkara zapota* L. P. Royen) based agroforestry system

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DOI: https://doi.org/10.33545/2618060X.2025.v8.i1Sb.2340

Abstract
The present trial was conducted with the aim to find the economics of tomato under sapota based agroforestry system in South Gujarat condition. The trial was undertaken at College Farm, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat during 2022-23. The experiment comprised of twelve treatments with three replications in Randomized Block Design. The highest net realization (₹ 4,44,661 ha^{-1}) and BCR (2.45) were recorded in 75% RDN through Neem coated urea + 25% RDN through Biocompost in open field condition. Similarly, the highest net realization (₹ 2,65,829 ha^{-1}) and BCR (2.50) were registered in 75% RDN through Neem coated urea + 25% RDN through Biocompost treatment which was followed by 100% RDN through Chemical Fertilizer (₹ 2,55,663 ha^{-1} and 2.42, respectively) under sapota based agroforestry system. Overall, in open condition and under sapota based agroforestry system, treatment 75% RDN through Neem coated urea + 25% RDN through Biocompost registered with the maximum net realization and BCR.

Keywords: Agroforestry, BCR, economics, sapota, tomato, yield

Introduction
Agroforestry is an innovative land-use system that integrates woody perennials (trees, shrubs, palm, bamboos, *etc.*) with agricultural crops and/or livestock in the same space of land to maximize ecological and economic benefits (Nair *et al.*, 2008) [25]. Recognized under the National Agroforestry Policy (Anonymous, 2014) [4] and the Sub-Mission on Agroforestry under National Mission on Sustainable Agriculture (Anon., 2016) [5], which promotes tree planting on farmlands and developing various agroforestry models with diverse cropping system for economic and ecological security. In all agroforestry land management, there are two essential and related aims which are- Agroforestry system should conserve and improve the site and optimize the combined production of trees, agricultural crops and animals simultaneously (Nayak *et al.*, 2021) [26].

An efficient agroforestry system would aim at systematically developing integrated land use system and practices where the positive interaction between trees and crops can be encouraged and maximized (Nayak *et al.*, 2021) [26]. This seeks to achieve a more productive, sustainable and diversified output from the land is possible with conventional monocropping system (Nair *et al.*, 2008) [25]. The farmers, mainly due to the economic benefits to them have adopted the trend of growing trees around agricultural land. It will be worthwhile to work out an integrated approach with the help of agricultural and forestry scientists, depending on the suitability of crop and location. Therefore, there is great need to identify the suitable agricultural crops, which are available for different agroforestry models. Intercropping of vegetables with fruit and other shrubs/ trees as subsidiary crop in terms of utilization of space and additional income is most suitable and viable option. The choice of intercropping is important as the economic return depends on particular tree species though the choice is also determined by the technical factors like agroclimatic and edaphic conditions. The cereals, vegetables, flowers and the medicinal plants are also grown as intercrops with varieties of tree plantations such as forestry plantations,

block plantations and orchards of horticultural tree species under agroforestry system (Nayak *et al.*, 2021; Willey, 1979) [26, 51].

Sapota or Sapodilla (*Manilkara zapota* L. P. Royen) belongs to family Sapotaceae is one of the potentials and widely adopted tropical fruit crop grown in southern Gujarat under rainfed and also under irrigated situation. Monoculture of fruit trees being risk prone, broad spacing provided to this crop provides an opportunity to an intercrop in the first few years, which generate additional income and improving productivity per unit area as a result of efficient utilization of natural resources and improved agroecological conditions. India is considered to be the largest producer of sapota in the world. The total area and production of sapota in India is 1.07 lakh hectares and 12.84 lakh tonnes, respectively in 2016-17. In Gujarat, the total area under sapota is 29.56 thousand hectares of which the production is 326.15 thousand tones and productivity is 11.03 MT per ha (Anon., 2018) [2]. Gujarat contributes 20.2 per cent in total production of sapota in India (Anon., 2010) [3]. Tomato (*Solanum lycopersicum* L.) is the most popular solanaceous vegetable crop grown all over the world because of its special nutritive and medicinal value. It is an annual herbaceous, day neutral plant and warm season crop reasonably resistant to heat, drought, tolerates partial shade and grows on wide range of soil and climatic conditions (Chaudhari, 2018) [8]. Tomatoes are important source of lycopene pigment (an antioxidant), ascorbic acid and beta carotene as well as valued for their colour and flavour due to carotenoids. India is the third largest tomato producer in the world after China and USA. India occupies 831 thousand hectares area with a total production of 203 lakh MT with productivity of 24.3 t/ha. In Gujarat, it occupies an area of 48.75 lakh ha with the total production of 13.95 lakh MT with a productivity of 29.0 t/ha (Anon., 2022) [1].

By intercropping vegetable crops with sapota, maximization in utilization of the sources of light and space. End of the *rabi* season increases the deficit of vegetables due to drought condition in South Gujarat and also increases the price of vegetables. Thus, by intercropping tomato with sapota in late *rabi* and late *kharif* seasons, there can be efficient utilization of resources and generation of more income. Given the long gestation period of sapota, developing a sustainable agroforestry model through compatible intercropping like tomato is essential to increase land-use efficiency and farmer's income. Keeping in view the above facts and economic importance of tomato and sapota crops, the present investigation was undertaken with the objective to study the economic performance of understorey tomato crop under the sapota based agroforestry system in South Gujarat condition.

Materials and Methods

Study area

The trial was carried out at College Farm (Block-A, Plot No-21), N. M. College of Agriculture, Navsari Agricultural University (NAU), Navsari, Gujarat, India during 2022-23. The experimental area is typically characterized by subhumid and warm monsoon with heavy rainfall (around 1500 to 1800 mm), moderately cold winter and fairly hot and humid summer. In general, monsoon commences in the second fortnight of June and retreats by the end of September. Most of the precipitation is received from South West monsoon, concentrated during the months of July and August. The winter season starts from November and ends by middle of February. The coldest months are December and January. Usually, the summer season commences during the middle of February and the temperature reaches to the maximum in the month of April and May, which are hottest months of the season. The mean minimum and maximum temperature during the course of experiment varied from 19.26 to 33.66 °C and the maximum average morning relative humidity recorded 88.16% and minimum 45.62% during late *rabi* and late *kharif* seasons of 2022-23.

Experimental details

The experiment was comprised of 12 treatments in both sapota orchard condition and open condition *viz.*, T_1- 100% RDF through Chemical Fertilizer (100:50:50 kg @ NPK kg ha^{-1}), T_2- 75% RDN through Neem coated urea + 25% RDN through Biocompost, T_3- 50% RDN through Neem coated urea + 50% RDN through Biocompost, T_4- 75% RDN through Neem coated urea + 25% RDN through Vermicompost, T_5- 50% RDN through Neem coated urea + 50% RDN through Vermicompost, T_6- 75% RDN through Neem coated urea + 25% RDN through FYM, T_7- 50% RDN through Neem coated urea + 50% RDN through FYM, T_8- 50% RDN through Neem coated urea + 50% RDN through FYM, T_9- Natural Farming + 1% Novel Plus, T_{10}- Natural Farming + 1% Novel Prime, T_{11}- Natural Farming + 5 ml/ litre (Each of Azotobacter, KMB, PSB) and T_{12}- Natural Farming with three replications in Randomized Block Design (RBD). The experiment was conducted in an already established seventeen years old plantation of sapota (*M. zapota* L. P. Royen) planted at 10 m x 10 m spacing. For the experiment, the seeds of GAT5 variety of tomato was collected from Department of Vegetable Science, Regional Horticulture Research Station, ASPEE College of Horticulture, NAU, Navsari and sown in the multi span sawtooth type Naturally Ventilated Poly House. The experimental field was fine tilth by two to three ploughings, clods crushing and harrowing with the tractor, followed by rotavator passes. Then, the experimental field was levelled and plots were prepared as per the details of experiment. Transplanting of seedlings was done 30 Days After Sowing (DAS) and planted at 60 cm x 45 cm. Immediate spot irrigation was applied to transplanted plants for better establishment and survival. Well decomposed farm yard manure (FYM) was applied uniformly to the entire experimental plot @10 t ha^{-1}. Phosphorus was applied in the form of single super phosphate and potash in the form of muriate of potash uniformly to the allotted treatment plots (T_1 to T_7) at the rate of 50 kg ha^{-1}. Nitrogen was applied in two equal splits; first half dose of nitrogen was applied as basal dose at the time of planting and remaining second half dose of nitrogen was applied in the form of neem coated urea after 45 days after transplanting (T_1 to T_7). Crop was irrigated immediately after each application of fertilizer. Further, manures such as biocompost, FYM and vermicompost were applied to plots in the treatments of T_2 to T_7 under sapota and open conditions whereas novel, novel plus and novel prime were applied to plots in treatments of T_8 to T_{10} under sapota and open conditions. In the remaining treatment T_{11}, under sapota and open conditions, 5 ml l^{-1} each of Azotobacter, KMB, PSB was applied. Moreover, jivamrut and ghanjivamrut were applied common to all the treatments of T_8 to T_{12} under sapota and open conditions initially and each 15 days interval up to flowering stage. Common irrigations were given through furrow irrigation system up to plant establishment. After maintaining proper crop stand, irrigation was given as and when needed. Gap filling was done to maintain required plant population for experimentation in the field at 10-15 Days After Transplanting during both the seasons of *late rabi* and *late kharif*. Hand weeding was done as and when needed to maintain the experimental field weed free during both the seasons of experimentation under open condition and sapota orchard.

Necessary plant protection measures were performed. Very less infestation of pest and disease were observed in the field. For the performance in terms of economics, the gross realization in terms of rupees per hectare was worked out on the basis of total crop yield. The prevailing market price of inputs and outputs was accounted to calculate the gross returns. Similarly, a gross return from the sapota was also worked out on the basis of yield of sapota plants. The cost of fertilizers was taken from current market price. The benefit cost ratio (BCR) was calculated by an incremental cost of different treatments and benefit obtain through an increase in production due to the respective treatments. The net returns per hectare were calculated by deducting the cost of cultivation from gross returns from tomato crop. The BCR was calculated as per formula in which net realization was divided by cost of cultivation. For analysing the economic performance, parameters of tree components such as tree height, GBH, crown spread (East-West and North-South direction) and yield of tomatoes were recorded and analysed as per the procedure described for RBD. The appropriate standard error of mean (S.Em. (±)) was calculated in each case and critical difference (CD) at 5% level of probability was worked out to compare the treatment means, where the treatment effects were significant.

Results and Discussion

Total fruit yield (t/ha)

The data on total fruit yield as affected by different INM treatments in sapota based agroforestry system and open condition during late *kharif* and *rabi* season are furnished in Table- 1. In sapota based agroforestry system, the effect of different INM treatments on total fruit yield was found significant and registered maximum in treatment T_2: 75% RDN through Neem coated urea + 25% RDN through Biocompost (6.86 t ha^{-1}) during late *kharif* season which was at par with T_4: 75% RDN through Neem coated urea + 25% RDN through Vermicompost (6.67 t ha^{-1}), T_6: 75% RDN through Neem coated urea + 25% RDN through FYM (6.54 t ha^{-1}), T_1: 100% RDF through Chemical Fertilizer (6.37 t ha^{-1}) and T_3: 50% RDN through Neem coated urea + 50% RDN through Biocompost (6.15 t ha^{-1}), whereas the lowest marketable fruit yield was recorded in treatment T_{12}: Natural Farming (4.21 t ha^{-1}). Moreover, in open condition marketable fruit yield was registered maximum in T_2 (34.57 t ha^{-1}) and found at par with T_4 (33.53 t ha^{-1}), T_6 (32.62 t ha^{-1}), and T_1 (31.63 t ha^{-1}) whereas it was recorded the lowest (20.29 t ha^{-1}) in treatment T_{12}. Similar trend was observed in late *rabi* and pooled analysis under sapota orchard and open condition for both the seasons.

Among the different treatments of integrated nutrient managements under sapota and in open condition yield attributes registered higher with application of combined 75% RDN through Neem coated urea and 25% RDN through Biocompost. This may be due to the combine use of organic with inorganic fertilizer encourages the vegetative and reproductive growth of tomato which ultimately increases the yield. Moreover, biocompost in combination with inorganic fertilizer gave significantly higher yield. It may be due to that biocompost helps for availability of nutrients coincides with crop demand at grand growth stage of crop. In addition, there might be improvement in productivity as a result of improved physical condition of the soil.

During the trial period, yield was recorded higher in open condition as compared to in sapota based agroforestry system. It might be due to the more intensity of light availability in open condition which in turn results in more photosynthetic activity as compared to under sapota based agroforestry system. At the same time, under sapota based agroforestry due to less availability of light reduced the yield parameters of tomato crop. The results are analogues with earlier findings of Cockshull *et al.* (1992) [9] in tomato; Jain and Singh (1999) [14] in wheat; Rao (2000) [37] in cowpea; Thakur and Singh (2002) [47] in black gram and peas; Rahman (2004) [34] in tomato, brinjal and chilli; Srinivas *et al.* (2008) [46] in coleus; Xiaobang *et al.* (2009) [52] in soybean and maize; Hanif *et al.* (2010) [12] in okra, Panneerselvama and Arthanarib (2011) [28] in sunflower; Sharma *et al.* (2011) [43] in wheat; Hasan *et al.* (2012) [13] in spinach and okra; Rakib (2013) [36] in radish; Lata *et al.* (2014) [22] in aswagandha; Tripathi *et al.* (2014) [48] in mungbean; Kumar *et al.* (2015) [20] in tulsi; Sondarva *et al.* (2018) [45] in brinjal and Mevada (2020) [24] in okra.

Table 1: Effect of various INM treatments on total fruit yield (t/ha) of tomato under sapota based agroforestry system and open condition

Treatments	Sapota orchard			Open condition		
	Late *rabi*	Late *kharif*	Pooled	Late *rabi*	Late *kharif*	Pooled
T_1 – 100% RDF through Chemical Fertilizer	5.45	6.37	5.91	27.90	31.63	29.76
T_2 – 75% RDN through Neem coated urea + 25% RDN through Biocompost	6.09	6.86	6.47	30.77	34.57	32.67
T_3 – 50% RDN through Neem coated urea + 50% RDN through Biocompost	5.37	6.15	5.76	27.21	30.52	28.87
T_4 – 75% RDN through Neem coated urea + 25% RDN through Vermicompost	6.08	6.67	6.37	29.95	33.53	31.74
T_5 – 50% RDN through Neem coated urea + 50% RDN through Vermicompost	5.26	6.11	5.69	26.54	29.83	28.18
T_6 – 75% RDN through Neem coated urea + 25% RDN through FYM	5.98	6.54	6.26	28.78	32.62	30.70
T_7 – 50% RDN through Neem coated urea + 50% RDN through FYM	5.21	5.95	5.58	25.99	29.34	27.66
T_8 – Natural Farming + 1% Novel	3.85	4.34	4.10	18.90	21.60	20.25
T_9 – Natural Farming + 1% Novel Plus	4.08	4.46	4.27	19.71	22.62	21.17
T_{10} - Natural Farming + 1% Novel Prime	4.18	4.58	4.38	20.39	23.19	21.79
T_{11} - Natural Farming + 5 ml/ litre (Each of Azotobacter, KMB, PSB)	3.82	4.39	4.10	18.63	21.36	20.00
T_{12} – Natural Farming	3.43	4.21	3.82	17.80	20.29	19.05
S.Em.± (T)	0.19	0.24	0.15	0.94	1.23	0.81
C.D. at 5% (T)	0.56	0.71	0.44	2.75	3.61	2.32
S.Em.± (S X T)			0.22			1.15
C.D. at 5% (S X T)			NS			NS
C.V.%	6.74	7.53	7.3	6.67	7.73	7.7

The results further revealed that fruit yield of tomato along with marketable yield were recorded higher with treatment 75% RDN through Neem coated urea + 25% RDN through Biocompost. It may be due to combine action of different yield attributing factors like fruit length, fruit diameter, number of fruits per plant, weight of fruit which were higher in same treatments. Similar results are also reported by Sendur *et al.* (1998) [41] in tomato, Sannigrahi *et al.* (2001) [40] in okra, Dwivedi and Thakur (2000) [10] in rice, Giraddi and Smitha (2002) [11] in chili, Poul *et al.* (2004) [33] in tomato, Anwer *et al.* (2005) [6] in French basil, Reddy and Reddy (2005) [38] in onion, Ullah *et al.* (2008) [49] in brinjal, Yadav and Yadav (2010) [53] in okra, Vijaya and Seethalakshmi (2011) [50] in eggplant, Jaisankar *et al.* (2014) [15] in okra, cowpea and sesame, Shanmugam and Ramamoorthy (2014) [42] in maize, Kumar (2016) [21] in brinjal, Sachan *et al.* (2017) [39] in okra, Meera Devi *et al.* (2018) [23] in capsicum, Kayesh *et al.* (2019) [17] in broccoli and Mevada (2020) [24] in okra.

Economics in open condition

The data with respect to benefit cost ratio (BCR) under open condition is presented in Table- 2. It is evident from data that tomato crop grown in open condition recorded the highest net realization as compared to integrated nutrient management under sapota based agroforestry system. The highest net realization (₹ 4,44,661 ha^{-1}) and BCR (2.45) were recorded in T_2: 75% RDN through Neem coated urea + 25% RDN through Biocompost in open field condition. Whereas, lowest net realization (₹ 3,24,845 ha^{-1}) and BCR (1.60) were recorded in T_7: 50% RDN through Neem coated urea + 50% RDN through FYM.

Economics of sapota based agroforestry system

The data regarding benefit cost ratio with sapota is presented in Table- 3. The BCR was noted maximum in sapota based agroforestry systems as compared to open condition. The highest net realization and BCR (₹ 2,65,829 ha^{-1} and 2.50, respectively) were registered in T_2: 75% RDN through Neem coated urea + 25% RDN through Biocompost which was followed by T_1: 100% RDN through Chemical Fertilizer (₹ 2,55,663 ha^{-1} and 2.42, respectively) under sapota based agroforestry system. Whereas, among intercrop under sapota the lowest net realization and BCR were registered in T_7: 50% RDN through Neem coated urea + 50% RDN through FYM (₹ 2,42,773 ha^{-1} and 2.17, respectively).

The net realization of tomato crop was recorded higher when grown in open condition whereas BCR recorded maximum under sapota based agroforestry system. Among different conditions of grow, the highest net realization and BCR were registered when tomato grown in open and under sapota based agroforestry system with the application of 75% RDN through Neem coated urea + 25% RDN through Biocompost (T_2). The probable reason for highest net realization in open condition is due to higher growth and yield attributes of tomato as compared to under sapota based agroforestry system. Moreover, maximum BCR in sapota based agroforestry system is due to fruit yield of sapota added to the yield of tomato and furthermore, 75% RDN through Neem coated urea + 25% RDN through Biocompost (T_2) resulted in higher BCR under sapota based agroforestry system due to higher yield of tomato having almost same quantity of sapota yield in all the remaining treatments. These results are in line with earlier findings of Patil *et al.* (1998) [31], Patil *et al.* (2010) [32], Hanif *et al.* (2010) [12], Panwar and Wani (2014) [29], Shukla (2014) [44], Yadav *et al.* (2014) [54], Ashalatha *et al.* (2015) [7], Nayak *et al.* (2014) [27], Kumar *et al.* (2016) [19], Rajalingam *et al.* (2016) [35], Kazi *et al.* (2017) [18], Patel *et al.* (2018) [30], Jilariya *et al.* (2019) [16] and Mevada (2020) [24].

Table 2: Economics of various INM treatments for tomato under open condition

Treatment	Yield (t/ha)	Fixed cost (₹)	Variable cost (₹)	Total cost (₹)	Gross realization (₹)	Net realization (₹)	BCR
T_1	28468	173811	5303	179114	569367	390253	2.18
T_2	31316	173811	7840	181651	626312	444661	2.45
T_3	27589	173811	10376	184187	551775	367587	2.00
T_4	30432	173811	16649	190460	608642	418182	2.20
T_5	26987	173811	27995	201806	539738	337931	1.67
T_6	29344	173811	17483	191294	586883	395589	2.07
T_7	26416	173811	29662	203473	528318	324845	1.60
T_8	19093	172782	32935	205717	572801	367084	1.78
T_9	19958	172782	33435	206217	598727	392510	1.90
T_{10}	20556	172782	33435	206217	616667	410450	1.99
T_{11}	18854	172782	32715	205497	565625	360128	1.75
T_{12}	17948	172782	31635	204417	538426	334009	1.63

Note: Tomato price: (T_1 to T_7) 20.00 per kg, Tomato price (T_8 to T_{12} NF based): 30.00 per kg

Table 3: Economics of various INM treatments for tomato under sapota based agroforestry system

Treatment	Tomato yield (kg/ha)	Fixed cost tomato (₹)	Variable cost tomato (₹)	Sapota yield (kg/ha)	Fixed cost sapota (₹)	Total cost (₹)	Gross realization (₹)	Net realization (₹)	BCR
T_1	5680	44923	1326	12390	59608	105857	361400	255663	2.42
T_2	6220	44923	1960	12390	59608	106491	372200	265829	2.50
T_3	5520	44923	2594	12390	59608	107125	358200	251195	2.34
T_4	6120	44923	4162	12390	59608	108693	370200	261627	2.41
T_5	5440	44923	6999	12390	59608	111530	356600	245190	2.20
T_6	6000	44923	4371	12390	59608	108902	367800	259018	2.38
T_7	5340	44923	7416	12390	59608	111947	354600	242773	2.17
T_8	3890	44660	8234	12390	59608	112502	364500	252118	2.24
T_9	4050	44660	8359	12390	59608	112627	369300	256793	2.28
T_{10}	4160	44660	8359	12390	59608	112627	372600	260093	2.31
T_{11}	3900	44660	8179	12390	59608	112447	364800	252473	2.25
T_{12}	3630	44660	7909	12390	59608	112177	356700	244643	2.18

Note: Tomato price: (T_1 to T_7) 20.00 per kg, Tomato price (T_8 to T_{12} NF based): 30.00 per kg

Conclusion

In the present trial, net realization was recorded highest in open condition whereas BCR was obtained maximum in sapota based agroforestry system with various integrated nutrient management treatments in open and sapota based agroforestry system. The highest net realization (₹ 4,44,661 ha^{-1}) and BCR (2.45) were recorded in 75% RDN through Neem coated urea + 25% RDN through Biocompost (T_2) in open field condition. Similarly, the highest net realization (₹ 2,65,829 ha^{-1}) and BCR (2.50) were registered in 75% RDN through Neem coated urea + 25% RDN through Biocompost (T_2) treatment which was followed by T_1: 100% RDN through Chemical Fertilizer (₹ 2,55,663 ha^{-1} and 2.42, respectively) under sapota based agroforestry system. Overall, in open condition and under sapota based agroforestry system treatment, 75% RDN through Neem coated urea + 25% RDN through Biocompost registered with the maximum net realization and BCR. On the basis of data of present investigation, it is advocated that growing of tomato crop under sapota can provide additional income to the farmer's community.

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