International Journal of Agriculture, Environment and Biotechnology
Citation: IJAEB: 9(4): 699-710 August 2016
DOI Number: 10.5958/2230-732X.2016.00091.7

AGRICULTURE ENGINEERING

Response of Drip Irrigation and Plastic Mulch on Quality of Sapota (*Achras Zapota*) Fruits

K.N. Tiwari*, Mukesh Kumar, Vikas Kumar Singh and D.T. Santosh

Precision Farming Development Centre, Department of Agricultural & Food Engineering, Indian Institute of Technology, Kharagpur- 721 302, West Bengal, India

*Corresponding author: vikas3234@gmail.com

Paper No. 494 Received: 13-2-2016 Accepted: 18-8-2016

Abstract

The field experiment was conducted to study the response of sapota (Achras zapota) crop under drip irrigation and plastic mulch. Different amounts of irrigation water application through drip and ring basin irrigation methods along with plastic mulch treatments were experimented with five replications. The Sapota crop water requirement was estimated using reference evapotranspiration data and crop co-efficient for different crop growth stages. Reference evapotranspiration was estimated using FAO-56 Penman Monteith approach. The irrigation water was applied at 60%, 80%, and 100% of the crop water requirement using drip and ring basin irrigation system. The quality analysis of sapota fruit was performed to investigate the effect of different treatments. Economic analysis was carried out to study the economic feasibility of using drip irrigation and plastic mulch for sapota cultivation. The water requirement of sapota crop varies between 10.71 L per day per plant in winter and 34.43 L in summer for the treatment of 100% water requirement of the sapota plant. The physical properties like fruit weight, volume, dimension, peel-pulp ratio was found to be increased due to increase in amount of irrigation water application from 60% to 100% using drip irrigation. A small decrease in true density of fruit was observed with the increase of size of fruit. The pH of fruit increased with decrease in irrigation water application through drip system. The TSS, total sugar and reducing sugar were estimated to increase with reduced irrigation water application. Sweetness of the fruit increased with reduced irrigation water application. Increase in Sapota fruit yield varied from 7.62% to 41% in mulched treatments. Increase in fruit yield by 21.05% for the drip treated plants was over ring basin. Based on the water use efficiency, benefit-cost analysis and fruit quality analysis 80% irrigation requirement supplied through drip system along with plastic mulch treatment can be recommended for Sapota irrigation.

Highlights

- Application of plastic mulch alone increased the yield of crop which varies from 7.62% to 41% in different irrigation treatments.
- Yield of sapota crop was found to increase by 21.05% due to drip in comparison to ring basin irrigation.
- Income from the sapota crop due to plastic mulch was found to vary between ₹ 18000 (US$ 324) and ₹ 46000 (US$ 828) per hectare of land under different treatments under investigation.
- Water use efficiency was found maximum for the treatment T4 (0.8VDM) as 6.71 kg ha^{-1} mm^{-1}.

Keywords: Drip irrigation, water requirement, plastic mulching, quality analysis, economic analysis

Drip irrigation is frequent application of water directly on or below the soil surface near the root zone of plants. Among different irrigation methods, the drip irrigation can increase irrigation water potential as well as crop yield. Optimum moisture level in the soil near the root zone area of the crop is critical to agriculture and plantation crops. Excess or deficit irrigation water supplies both are harmful to crop growth and yield. Optimal and precise irrigation water supply can be maintained through drip irrigation. Drip irrigation is more suitable for the areas of water scarce because runoff, deep percolation and evaporation are greatly reduced. Strategically deficit water supply through drip irrigation can save both water and energy input. In general, water management assumes paramount importance to reduce the wastage of water. It is also necessary to increase the water use efficiency (WUE) and to ensure equitable water distribution. Precise estimation of evapotranspiration demand of a crop is important to supply irrigation water.

There are several methods to determine evapotranspiration. The climatological based FAO-56 Penman Monteith method is sole accurate method to determine reference evapotranspiration. There are several investigators (Singh *et al.,* 2007 and Gontia, 2007) used this method for estimation of reference evapotranspiration.

Sapota (Family: *Sapotaceae*) is a native of tropical America and it probably originated from Southern Mexico or Central America. The sweet testing fruit possesses a delicate characteristic aroma, sometimes slightly astringent. Unlike many other plant species the Sapota plant has the unique characteristic of flowering and fruiting all through out the year, which helped making this plant a hot favourite to many Horticulturists. The grafted variety of Sapota (Cv. Kalipatti) of one year old was planted on 4th October 2005 in the Precision Farming Development Centre Project experimental farm of agricultural and Food Engineering Department, IIT Kharagpur, which almost 5 years old now. Being a tropical fruit crop it can be grown from sea level upto 1200 m above MSL. It needs warm (10-38^{O} C) and humid climate (70% relative humidity) for growth and can be cultivated throughout the year. Alluvial, sandy loam, red laterite and medium black soils with good drainage are ideal for cultivation of Sapota. The fruit is a large ellipsoid berry, 4–8 cm in diameter, very much resembling a smooth-skinned potato and containing 2-5 seeds. From the inside, its flesh ranges from a pale yellow to an earthy brown color with a grainy texture. The fruit has a high latex content and does not ripen until picked.

The process of covering the soil surface around the plant root area with organic materials (dry leaves, straw, hay, stones etc.) and synthetic material (plastic film) is known as mulching. The plastic mulch plays important role for conservation of moisture, weeds control and moderate soil temperature which enhances better root growth and higher crop yield (Ramakrishna, 2006, Tiwari *et al.,* 1998). Dark opaque plastic mulches or clear mulche applied above the soil surface intercept sunlight which causes warming of soil that encourages faster growth as well as early fruiting. White mulch reflects solar radiation from the sun effectively reducing soil temperature. This reduction in temperature may help to establish plants in mid-summer when cooler soil might be required. Plastic mulches reduce the amount of water lost from the soil due to evaporation. This means less water will be needed for irrigation. Plastic mulches also aid in evenly distributing moisture to the soil which reduces plant stress.

Quality is very important aspect of any fruit crop. A good quality produce has always good demand in the market and fetches high prices. Fruits are the most important composition of a healthy diet, which is packed with vitamins, minerals and other rich nutrients. Quality deals with the both physical properties and chemical composition of fruits. For the fruit crops, fruit should have good physical appearance in size, volume, weight, color, firmness to attract the consumer and also should be rich in vitamins, sugar and minerals for health benefits. Ultimately, it should be tasty for eating by which it is liked by any consumer. Sapota juice is a good source of sugar, proteins, ascorbic acid, phenolics, carotenoids and minerals like iron, copper, zinc, calcium and potassium (Kulkarni *et al.* 2006). *There are various nutrients needed by the crop to normal functioning of its metabolic activities and to be disease free.* Trees must be healthy to *produce good quality fruit*. Weak or diseased trees produce either poor quality fruit or no fruit at all. Fruit weight, volume, and pulp/pit ratio increases with the increase in irrigation water level as water availability influences cell division more than cell expansion but no influence on fruit shape (Proietti and Antognozzi, 1996).

Bryla *et al.* (2009) reported that yield and fruit weight of blue berry fruit was highly influenced by drip irrigation and plastic mulch treated plants as compared to overhead sprinkler and microsprays. Yield and berry weight were also higher on average when plants were irrigated at 100% ETc than at 50% ETc. Study was conducted by Khattab *et al.*, 2009 on olive fruit with different level of irrigation on fruit quality. This study indicated that fruit weight, volume, length, diameter and flesh thickness and moisture were increased under the 100% irrigation level with drip as compare to deficit irrigation.

Drip irrigation requires fixed capital investment for installation of drip system. The amount of investment depends upon the type of the crop, plant spacing, type of dripper and its discharge capacity and the location of the water source in the farm. Close spacing crops require relatively higher capital cost than wide spaced crops. The other investments include operation and maintenance cost of drip system, cost of fertilizer, water cost, labour cost etc. Any cultivator would prefer to adopt drip method of irrigation, if the system is economically viable for a given crop. Any new technology for crop production would be acceptable if higher crop production as well as greater B.C. ratio is assured. Hence yield and quality of the crop produce should be high so as to overcome investment.

In this research paper field experiment has conducted to study the effect of combined treatment of irrigation and plastic mulch on sapota crop grown in sub humid and sub tropical climate. The influence of drip irrigation and plastic mulch on crop yield and fruit quality has been investigated. The study also explores to evaluate the economics of using drip irrigation and plastic mulch on sapota cultivation.

Materials and Methods

Description of study area

The study area is located at Experimental Farm of Precision Farming Development Centre, Agricultural and Food Engineering Department, IIT Kharagpur, India. It is situated at 22° 20′ N latitude and 87° 20′ E longitude and at an altitude of 48 m above the mean sea level. The climate of the region is sub-humid, with average annual rainfall of about 1400 mm. The minimum temperature varies from 9.6 °C to 27 °C and maximum temperature ranges from 27.2 °C to 41.8 °C for the winter and summer seasons respectively. The maximum and minimum relative humidity varies from 79-99% and 19-78 % throughout the year.

Crop experimental and field layout details

Experiments were conducted on sapota crop that belongs to Sapotaceae family of Kalipatti variety. Sapota is a tropical fruit crop which it can be grown from few meter above mean sea level to 1200 m above m.s.l. It needs warm (10-38^{o} C) and humid climate (70% relative humidity) for growth and can be cultivated throughout the year. Alluvial, sandy loam, red laterite and medium black soils with good drainage are ideal for cultivation of sapota. The fruit is a large ellipsoid berry, 4–8 cm in diameter, very much resembling a smooth-skinned potato and containing 2-5 seeds. From the inside, its flesh ranges from a pale yellow to an earthy brown color with a grainy texture. The fruit has a high latex content and ripens after maturity and picked from plants.

The experimental field of sapota is rectangular in shape with 40 m long and 25 m wide. The crop was planted on 4th October 2005 in the PFDC farm which is now ten years old. The plant to plant and row to row distance is 5m × 5m. Forty plants were taken for field experiment. The topography of the land area is plain and it has sandy-loam soil texture. Farm Yard Manure (FYM) at the rate of 15 kg was applied to each plant and thoroughly mixed with the soil before planting. All treatments received a total of 100g N, 50g P_2O_5, 50g K_2O per plant at the first year. Dosages were increased to 25 kg of FYM, 300g N, 150g P_2O_5, 200g K_2O per plant per year from 3rd year onwards. The phospetic and potassic fertilizers were applied twice in a year as a basal along with FYM i.e. Pre and Post monsoon and nitrogenous fertilizer was applied at 20 days interval through fertigation. Standard package of practice was followed for growing the crop. Pest and disease infested shoots were removed at regular intervals. The plant was trained every year before monsoon to maintain a good shape of the canopy and for better intercultural operation.

The total length of lateral used in the field was 150 m. Seventy drippers of different discharge combinations were used in drip irrigation experiment. The water supply in laterals was controlled by the gate valves provided at the entry end of each lateral. The operating pressure of about 1 kg/cm^2 was maintained to obtain design dripper discharge. The black plastic film of 100μ thickness was used as mulch material. The size of plastic mulch was 2m × 2m for each plant. The plastic mulch was placed above the drip lateral so as to prevent evaporation loss. The layout of the field and the division of plots along with the laterals fitted with drippers is shown through Fig.1.

The influence of different levels of irrigation treatments through drip system alone and along with plastic mulch was experimented to study the crop response and compared with basin irrigation. There were total eight treatments in eight rows and five plants in each row given different amount of irrigation water supply.

The following treatments were experimented for the study as stated below:

- T_1: 100% of irrigation requirement supplied through drip (VD)
- T_2: 100% of irrigation requirement supplied through drip and plastic mulch (VDM)
- T_3: 80% of irrigation requirement supplied through drip (0.8VD)
- T_4: 80% of irrigation requirement supplied through drip and plastic mulch (0.8VDM)
- T_5: 60% of irrigation requirement supplied through drip (0.6VD)
- T_6: 60% of irrigation requirement supplied through drip and plastic mulch (0.6VDM)
- T_7: 100% of irrigation requirement supplied through ring basin and plastic mulch (VRBM)
- T_8: 100% of irrigation requirement supplied through ring basin (VRB)

Randomized block design was used to supply irrigation water to plants at different irrigation levels. Five of plants for each treatment were randomly selected to supply irrigation water either by drip system or through ring basin. Treatments T_1 and T_2 had combination of two drippers of 4 lph and one dripper of 2 lph discharge. Treatments T_3 and T_4 had two drippers of 4 lph discharge and Treatments T_5 and T_6 had combination of one dripper of 4 lph and one dripper of 2 lph discharge. In treatments T_7 and T_8 100% irrigation was given through ring basin, however treatment T_7 had also plastic mulch.

Estimation of irrigation water requirement

The daily irrigation water requirement for the Sapota crop was estimated by using the following relationship

$$WR = ET_o \times K_c \times W_p \times A \qquad \text{------ (1)}$$

Where,

WR = Water requirement by the crop (L d^{-1})

ET_o = Reference evapotranspiration (mm d^{-1})

K_c = Crop coefficient

W_p = Wetting fraction

A = Plant area (m^2)

Net irrigation water requirement was estimated by using equation 2.

$$IR = ET_0 \times Kc \times W_p \times A - Re \times W_p \times A \qquad \text{------(2)}$$

Where,

IR = Net irrigation requirement (L d^{-1})

Re = Effective rainfall (mm d^{-1})

Irrigation water was supplied in ring basin, drip system and drip with plastic mulch treated plots to meet irrigation requirements. The time of operation of the drip system was determined based on emitter discharge and volume of water to be delivered in different treatments. Alternate day irrigation interval was made for the plants under treatments T_1 to T_6 in case of drip irrigation and for the irrigation treatments T_7 and T_8 (ring basin) water was applied at five days interval directly to the basin. Wetting percent was decided based on average canopy growth of the plant (Cetin and Uygan, 2008), as the canopy area increases the wetted fraction also increased. In case of ring basin irrigation wetting fraction was more than the drip irrigation due to larger volume of water supply of 5 days irrigation interval.

Biometric crop response and sapota fruit quality analysis

Biometric observations on plant canopy diameter, height, girth and number of branches were recorded at three months interval for the plants under different treatments in order to monitor the influence of irrigation treatments and plastic mulch on crop growth. Treatment-wise samples were collected from the sapota crop field to evaluate the influence of various treatments on the quality of sapota fruit. Harvesting was done by picking the fruit directly from the sapota tree before it has attained full maturity level and these were ripen at normal temperature until the fruit softened a bit and the inner flesh was no longer green in colour and fruit was slightly soft. The different physical quality parameters such as size, weight, volume, bulk density, seed-peel-pulp ratio were determined. Chemical properties of sapota fruit such as moisture content, ascorbic acid, TSS, sugar content, titrable acidity and ash content were analyzed using standard procedure.

Economic analysis

Drip irrigation and plastic mulch involve fixed capital cost and thus, it is necessary to take into account the income and cost of system for the whole life span of both investments. The seasonal cost of drip irrigation system and plastic mulch considers depreciation, prevailing bank interest rate, repair and maintenance of the drip system. The interest rate and repair and maintenance cost of the drip system were assumed 9% and 1% per annum of the fixed cost respectively (Pattanaik *et al.,* 2003). The useful life of drip system and plastic mulch were considered to be 7 and 5 years respectively. The production cost of sapota cultivation includes expenses incurred in field preparation, cost of grafted plants, soluble fertilizers, crop protection measures, irrigation water and harvesting.

Turmeric (Cv- PCT-13) was used as intercrop. The spacing of main crop (Sapota) is 5 × 5 m^2 and leaving 1 m from each side, the rest area of 15 m^2 could be effectively utilized by intercrop in a bed of 3 m × 5 m. Irrigation and other management practice were followed separately. Usually, 50 tonnes of farmyard manure was applied at the time of preparing the land. However, chemical fertilizers @ 30 kg each of N, and P_2O_5 and 60 kg of K_2O per ha were applied after planting, in two split doses, the first two months after planting and the second a month and a half later. Harvesting was done after maturity (210 DAP). Cost of cultivation of turmeric crop, includes seed, labour, charges towards water and electricity. Economic analysis was performed to estimate the benefit cost ratio of different treatments.

Results and Discussion

Water requirement of sapota crop

Estimation of crop water requirement is important for design of irrigation system. Reference evapotranspiration was estimated using FAO-56 Penman Monteith approach. The irrigation water requirement of sapota crop was estimated from FAO-56 approach using climatic and rainfall data of previous ten years (2005-14). The net irrigation was estimated using Equation 2.

Evapotranspiration of the sapota crop was computed using FAO-56 Penman Monteith approach and crop coefficient values. The crop coefficient was used from the literature available locally and similar crop information in Allen et al. (1998). Fig. 2 shows the weekly variation in crop evapotranspiration (ETc) for whole year. The maximum weekly evapotranspiration was found as 21.26 mm for 18^{th} week and minimum value as 6.62 mm in 51^{st} week. Water requirement of sapota crop was estimated considering the percentage of canopy cover. It was calculated based on average maximum canopy growth of the plants measured for the particular treatment.

The crop water requirement was estimated for 52 weeks for different treatments. Water requirement of sapota crop varies as evapotranspiration varies throughout the year and goes maximum in summer season and minimum in winter season. The maximum value of crop water requirement was found as 34.43 L d^{-1} $plant^{-1}$ in 18^{th} week (May month) and minimum value as 10.71 Ld^{-1} $plant^{-1}$ in 51^{st} week (December month) for 100% crop water requirement. These estimated values of crop water requirement can be used for crop irrigation planning and designing.

Effect of drip irrigation and plastic mulch on biometric response and crop yield

Treatment-wise biometric attributes of the study crop were measured for six years (April 2008 to April 2013). Table 1 shows response of biometric parameters under different treatments.

Analysis of biometric attributes results show that the drip irrigation along with plastic mulch had definite greater influence on plant growth and yield in comparison to combination of ring basin irrigation and plastic mulch (T_7) and also without mulch (T_8). However all the biometric attributes were statistically at par at 80% and 100% irrigation levels with plastic mulch (T_2 and T_4) and non-significant for canopy development. The analysis of sapota fruit yield results (Fig. 3) show that the yield values are statistically significant for different treatments under study. The sapota yield was found to increase as the amount of irrigation water supply was increased from 60% to 100% of irrigation requirement. The highest yield of 16.1 t ha^{-1} was found in treatment T_2 followed by T_4 (15.60 t ha^{-1}) which was statistically at par with T_2. It is further investigated that with the same level of water application between two treatments, the yield was always greater for mulch treated plants. This could be due to better soil conditions in the plant root zone as compared to non mulched condition. In China by Wu *et al.*, 1999 and Liu and Wu, 2003 conducted experiments on rice crop reported greater yield in mulched treatments.

The crop yield was estimated to be 21.05% greater in drip irrigation (T_1) than the conventional ring basin irrigation (T_8). This could be due to reduction in bulk density and increased soil porosity caused by better root environment. At 80% irrigation water requirement met through drip (T_3). Similarly the fruit yield was about 17.89 per cent greater over conventional ring basin irrigation at 60% irrigation water supply met through drip (T_5). The yield was reduced marginally by 0.32 per cent over ring basin irrigation (RB), however it is statistically at par. This shows that in water scarcity region the drip irrigation is a viable option to cultivate crop due to 40% saving in irrigation water.

Effect of drip irrigation and plastic mulch on quality of sapota fruit

To assess the influence of various amount of water supplied through drip system and plastic mulch on quality of fruit, the physical and chemical properties of sapota fruit were evaluated following the procedures suggested by Ranganna (2001). The treatment-wise average value of results of the analysis is shown in Table 2 and Table 3.

Table 2 shows the change in physical properties of the sapota fruit due to drip irrigation and plastic mulch treatments. From the analysis it is revealed that different treatments have direct influence on the fruits weight, with the increase in irrigation level the weight of the sapota fruit was found to increase. With the same level of water requirement between two treatments there is an increase in fruit weight for the treatment of soil covered with plastic mulch. The maximum fruit weight was found as 81.43 g for drip irrigation water and plastic mulch (T_2) and minimum as 65.08 g under treatment T_5 (i.e. 0.6 VD).

Analysis of results revealed that the size and volume of the sapota fruit was also found to increase with the increase in amount of irrigation water applied through drip irrigation as well as plastic mulch. Maximum volume was found for the treatment T_2 (VDM) for maximum as 88.2 cm^3 and minimum as 68.3 cm^3 under the treatment T_5 (0.6 VD).

Further it was also revealed that the true density of the sapota fruit was found slightly greater with reduced amount of water application through drip and plastic mulch for treatment T_6 (0.6 VDM). The maximum density was found as 0.958 g cm^{-3} in treatment T_6 and minimum as 0.916 g cm^{-3} for the treatment T_1 (VD).

It was also found that there was increase in the overall fruit dimension with the increase in the amount of the water applied to the crop. The lowest value was found for the treatment T_5 (0.6 VD) as 49.55 mm × 48.76 mm × 48.35 mm and highest as 52.91 mm × 52.25 mm × 52.15 mm for the treatment T_2 (VDM).

The peel and pulp ratio was also found to be highest under treatment T_2 (VDM) followed by the treatment T_1 (VD). The minimum ratio was obtained under treatment T_8 (VRB). However, no definite trend was found under any treatment for number of seeds. It is found that the peel-pulp ratio increased due to increase in amount of irrigation water application. The use of plastic mulch along with irrigation also increased the peel-pulp ratio.

The results of chemical analysis of sapota fruit is given in Table 3. Analysis of results in Table 3 shows that with the reduced application of irrigation water supply, the pH of the fruit was found to be slightly increased. The maximum pH of the fruit was found as 5.12 in treatment T_5 (0.6VD) and minimum as 4.52 in treatment T_2 (VDM). It is interesting to note that fruits pH get reduced due to applications of plastic mulch and irrigation water. The ascorbic acid content in Sapota fruit was found to be greater for all the fruits for soil covered with plastic mulch and drip irrigated plots as compared to non plastic mulched plots. The highest ascorbic acid content was as 14.3 mg in Sapota fruits of treatment T_2 (VDM) and lowest for the fruits under treatment T_5 (0.6VD) as 11.8 mg per 100 g of edible fruit.

Further analysis of Table 3 also revealed that the moisture content of the fruit was found to greater for greater volume of irrigation water application through drip with plastic mulch. The maximum value was found in treatment T_2 (VDM) as 74.88% and minimum as 68.54% in treatment T_5. The amount of moisture content was greater in fruits of mulch treated as compared to same amount of irrigation water supplied without mulch.

The ash content of fruit was found greatest for the plants given irrigation through drip with plastic mulch (T_2) as 0.746% and minimum for the treatment T_5 as 0.533%. Results in Table 3 showed that the titrable acidity was found to be reduced due to decreased irrigation water supply. The minimum value was found as 0.15% in treatment T_6 and maximum as 0.19% in treatment T_1. Further chemical analysis of fruits showed that with decreased irrigation water application (i.e from VD to 0.6 VD) the total soluble solid (TSS), total sugar (TS) and reducing sugar content were found to be increased. With the same level of irrigation water application, there was increase in all these values for the fruits of plants having drip irrigation and plastic mulch as compared to being without mulch. The maximum values of TSS, total sugar (TS), reducing sugar (RS) were found in treatment T_6 (VDM) as 20.1 ^{o}Brix, 13.90% and 11.32% respectively and minimum value as 16.4 ^{o}Brix, 10.21% and 9.52% respectively in treatment T_1 (VD). The ^{o}Brix to acidity ratio was found to increase as the amount of irrigation water application to the crop decreased which reveals that as irrigation water level decreases the sweetness of the fruit increases. The maximum value of this ratio was found as 134.0 in treatment T_5 (0.6 VD) and minimum value as 86.3 in treatment T_1 (VD). In addition to this it was also found that with the same level of irrigation water application through drip the ^{o}Brix to acidity ratio was greater in the fruit of mulched plants than non mulched plants (Table 3). This study reveals that irrigation water application through drip and use of plastic mulch has definitely improved the quality of Sapota fruits.

The findings of biochemical analysis of Sapota fruit under full volume of irrigation water with plastic mulch treated plants were similar in line with the results as reported by Bryla *et al.* (2009) that drip generally produced higher yields and larger berries in blueberry fruit with much less water than sprinklers or microsprays. Khattab *et al.* (2009) also proved that fruit weight, volume, length, diameter and flesh thickness and moisture increased under the 100% irrigation level through drip in olive fruit.

Economic analysis

The economic analysis of the project was carried out to evaluate the economic feasibility of using drip irrigation and plastic mulch for cultivation of Sapota crop. In this study economics of different treatments have been evaluated for irrigation through drip system with and without plastic mulch and ring basin with and without plastic mulch. The costs under different treatments include cost for planting materials, field preparation, installation of drip, plastic mulching, fertilizer, manures, plant protection materials, water, electricity, labour, operation and maintenance costs etc. for cultivation of Sapota crop in one hectare. Cost and benefits under different treatments were estimated on annual basis. The economic feasibility of the different treatments was determined by evaluating the Benefit-Cost ratio.

The life of drip system components and plastic mulch film were considered as 7 and 5 years respectively based on the available literature (Rao, 1994). The annual cost was estimated using the prevailing interest rate for agricultural purpose as 9% and repair and maintenance cost as 1% of the fixed cost.

The cost of 100 μm thick black plastic mulch was taken as ₹ 140/kg (US$ 2.52/kg) (1kg 100 μm thick film covers 10.74 m^2 surface area). The cost of mulch cover (2m × 2m) for each plant for one hectare of land was estimated as ₹ 42,280/- (US$ 761.04).

The total amount of water required annually for one year for 100% irrigation is 2906 mm. Assuming the cost of irrigation water as @ ₹ 4×10^{-2} / L, the total cost of irrigation water would be ₹ 1318 (Kumar 2010). Similarly, cost of irrigation water is calculated for other treatments (Table 4). The electricity charge for pump operational hours @ ₹ 4 per kilowatt hour is estimated as ₹ 1105 (US$ 19.89) which is considered same for all treatments. The labour

Table 1. Effect of plastic mulch and drip irrigation on biometric attributes and Sapota yield

Treatment	Plant height (m)	Girth (cm)	No. of primary branches	Canopy (m)	Yield (t/ha)
T_1 (VD)	4.55	37.30	13.40	4.12	11.50
T_2 (VDM)	4.82	39.10	14.00	4.34	16.10
T_3 (0.8VD)	3.90	38.30	11.00	3.85	11.20
T_4 (0.8VDM)	4.00	39.00	12.60	3.85	15.60
T_5 (0.6VD)	4.81	36.20	10.80	3.83	9.20
T_6 (0.6VDM)	3.95	37.40	11.20	3.89	11.04
T_7 (RBM)	3.92	30.90	11.60	3.98	11.04
T_8 (RB)	3.75	30.00	11.20	3.65	9.50
S.Em (±)	0.242	2.057	0.704	0.403	0.903
CD (P=0.05)	0.603	5.122	1.753	NS	2.248

Table 2. Effect of drip irrigation and plastic mulch on physical properties of sapota fruit

Treatment	Weight (g)	Volume (cm^3)	True density (g cm^{-3})	Dimension (mm)	Peel: Pulp: Seed ratio
T_1 (VD)	78.73	85.9	0.916	53.46 × 51.46 × 51.05	6.81 : 70.05 : 1.84
T_2 (VDM)	81.43	88.2	0.923	52.91 × 52.25 × 52.15	7.70 : 72.12 : 1.59
T_3 (0.8VD)	75.45	80.8	0.933	52.45 × 51.40 × 50.81	5.84 : 68.04 : 1.47
T_4 (0.8VDM)	77.15	81.9	0.942	52.30 × 51.65 × 51.52	5.82 : 68.65 : 2.61
T_5 (0.6VD)	65.08	68.3	0.952	49.55 × 48.76 × 48.35	5.32 : 58.56 : 1.12
T_6 (0.6VDM)	67.29	70.2	0.958	50.13 × 49.21 × 48.95	5.66 : 60.25 : 1.24
T_7 (RBM)	73.78	78.1	0.944	51.40 × 50.76 × 50.46	5.74 : 66.41 : 1.56
T_8 (RB)	70.24	75.4	0.931	51.08 × 49.79 × 49.78	5.65 : 63.16 : 1.34

Table 3. Effect of drip irrigation and plastic mulch on chemical properties of sapota fruit

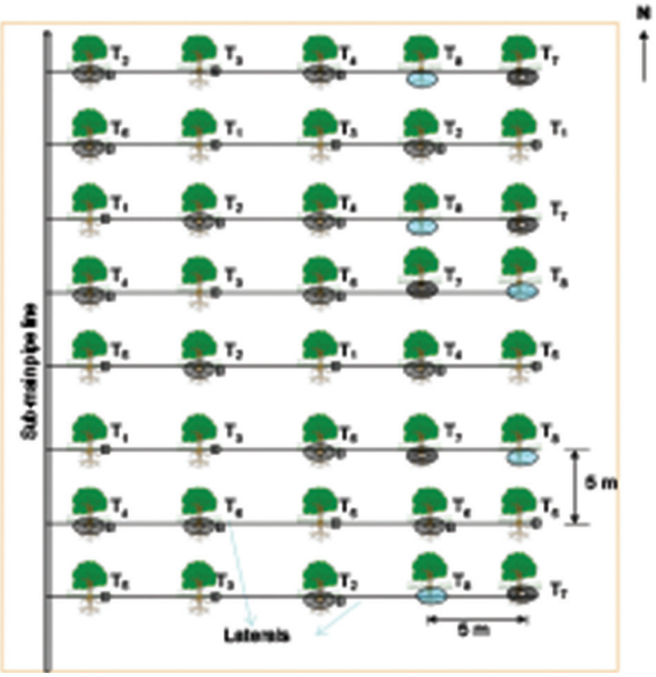
Treatment	Moisture content (% wet basis)	TSS (°Brix)	pH	Titratable Acidity (%)	Ascorbic acid (mg/100 g)	Total sugar (%)	Reducing sugar (%)	Ash content (%)	°Brix/acid
T_1 (VD)	72.03	16.4	4.66	0.190	14.1	10.21	9.52	0.688	86.3
T_2 (100VDM)	74.88	16.9	4.52	0.181	14.3	10.34	9.56	0.746	93.3
T_3 (0.8VD)	70.92	17.2	4.95	0.170	13.4	12.72	10.54	0.586	101.2
T_4 (0.8VDM)	69.95	17.8	4.80	0.166	13.7	12.95	10.91	0.716	107.2
T_5 (0.6VD)	68.54	19.7	5.12	0.154	11.8	13.41	11.10	0.533	127.9
T_6 (0.6VDM)	67.11	20.1	5.01	0.150	12.2	13.90	11.32	0.601	134.0
T_7 (RBM)	69.85	19.1	4.92	0.165	12.1	12.52	10.70	0.710	115.7
T_8 (RB)	69.71	18.3	5.05	0.159	11.9	12.33	10.12	0.591	115.1

Table 4. Economic analysis of Sapota crop cultivated in 1 ha with drip irrigation and plastic mulch for different treatments

Cost of economics per hectare of land	T_1 (VD)	T_2 (VDM)	T_3 (0.8VD)	T_4 (0.8VDM)	T_5 (0.6VD)	T_6 (0.6VDM)	T_7 (RBM)	T_8 (RB)
1. Cost of installation of drip	45000	45000	45000	45000	45000	45000	—	—
(a) Life in years	7	7	7	7	7	7	—	—
(b) Depreciation amount (₹)	6429	6429	6429	6429	6429	6429	—	—
(c) Interest @ 9% (₹)	4050	4050	4050	4050	4050	4050	—	—
(d) Repair and maintenance @ 1% (₹)	450	450	450	450	450	450	—	—
(e) Annual cost of installation of drip{1(b)+1(c)+1(d)}(₹)	10929	10929	10929	10929	10929	10929	—	—

2. Cost of mulching (₹)	—	42280	—	42280	—	42280	42280	—
(a) Life in years	—	5	—	5	—	5	5	—
(b) Depreciation amount (₹)	—	8456	—	8456	—	8456	8456	—
(c) Interest @ 9% (₹)	—	3805	—	3805	—	3805	3805	—
(d) Annual cost of mulching {2(b)+2(c)} (₹)	—	12261	—	12261	—	12261	12261	—
3. Total annual fixed cost {1(e)+2(d)} (₹)	10929	23190	10929	23190	10929	23190	12261	—
4. Water used (mm)	2906	2906	2325	2325	1744	1744	2906	2906
5. Cost of fertilizers used (₹)	7500	7500	7500	7500	7500	7500	7500	7500
6. Charges on water @ 4 paise per litre (₹)	1318	1318	1054	1054	791	791	1318	1318
7. Electricity charges @ 4 rupees per unit (₹)	1105	1105	1105	1105	1105	1105	—	—
8. Labour charges @ 150 rupees per day (₹)	9000	7500	9000	7500	9000	7500	9375	10875
9. Yield of produce (t/ha)	11.5	16.1	11.2	15.6	9.2	11.04	11.3	9.5
10. Income from produce @ 10 rupees per kg (₹)	115000	161000	112000	156000	92000	110400	113000	95000
11. Additional expenditure to Intercrop (Turmeric) (₹)	13100	13100	13100	13100	13100	13100	13100	13100
12. Additional income from Intercrop (₹)	31688	31688	31688	31688	31688	31688	31688	31688
13. Gross cost of production (3+5+6+7+8+11) (₹)	42952	53713	42688	53449	42425	53186	43554	32793
14. Gross Income (10+12) (Rs.)	146688	192688	143688	189688	123688	142088	144688	136688
15. Gross benefit cost (B-C) ratio (14/13)	3.42	3.59	3.37	3.55	2.92	2.67	3.32	4.17
16. Water use efficiency (kg $ha^{-1}mm^{-1}$)	3.96	5.54	4.82	6.71	5.23	6.33	3.89	3.27

Current Exchange value of rupees in US dollar: (1 US $ = ₹ 67.5)



T_1=VD, T_2=VDM, T_3=0.8VD, T_4=0.8VDM, T_5=0.6VD, T_6=0.6VDM, T_7=RBM, T_8=RB

Fig. 1: Experimental field layout of different irrigation levels and plastic mulch treatments

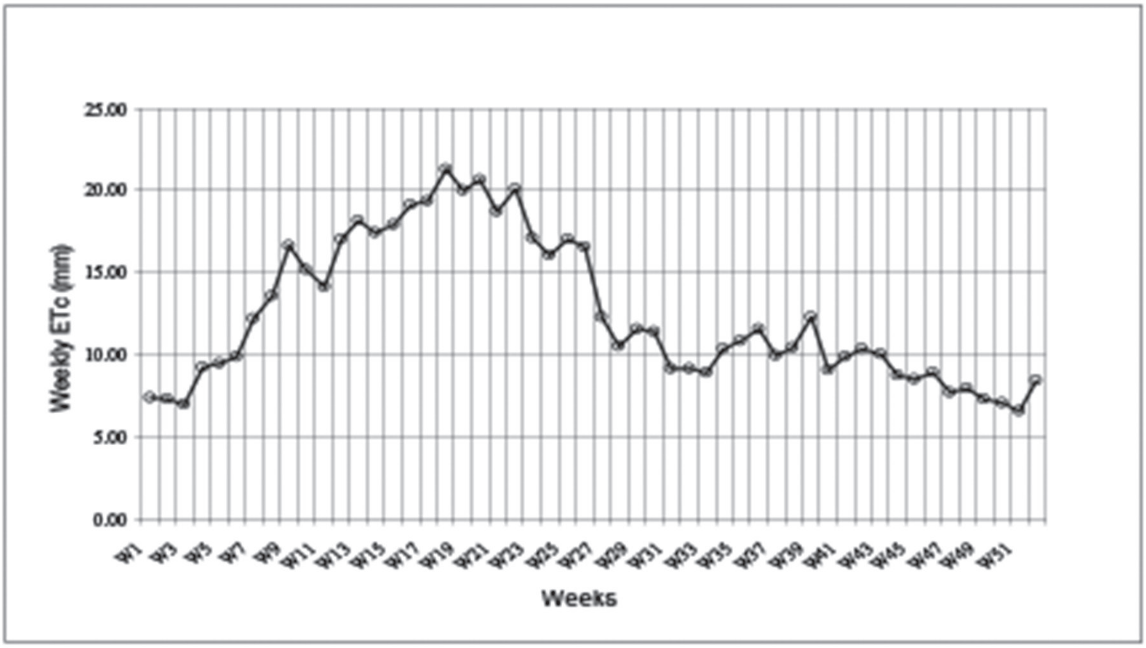


Fig. 2: Weekly evapotranspiration of sapota crop (ETc)

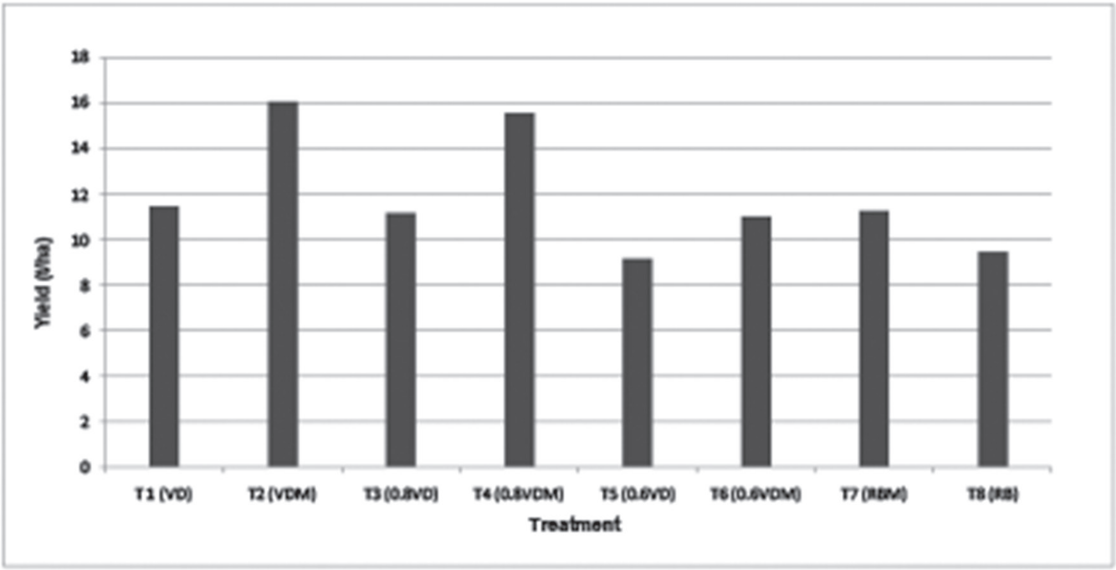


Fig. 3: Yield of the sapota crop in different treatments

charge is calculated based on man-hours required for different treatments @ ₹ 150 (US$ 2.7) per day for 8 working hours in a day. The man-hours for the treatments containing drip alone, drip with mulch, ring basin with mulch and ring basin alone was found to be 480, 400, 500 and 580 respectively.

The income from produce under different treatments considering sale price of @ ₹ 10 (US$ 0.18) per kg of sapota fruit was found to vary between ₹ 1,15,000 (US$ 2070) and 1,61,000/-(US$ 2898) from one hectare of land. The maximum income was found for the treatment drip irrigation with plastic mulch (VDM) and minimum for the treatment having ring basin irrigation given with 100% irrigation water (T_8-RB).

Turmeric was cultivated as inter crop to utilize the space left between plants. The total investment made for cultivation of turmeric intercrop was estimated as ₹ 13,100 (US$ 235.8). The additional income gained due to intercrop was ₹ 31,688 (US$ 570.38). The gross cost of production was estimated to vary from ₹ 32,793(US$ 590.27) (T_8) to ₹ 53,713 (US$ 966.83) (T_2) for different treatments. Gross income gained from these respective treatments was found to be maximum as ₹ 1,92,688 (US$ 3468.38) for treatment T_2 (VD) and minimum as ₹ 1,36,68 (US$ 246) for treatment T_8 (VRB).

It can be seen from the Table 4 that the Benefit-Cost ratio was highest in ring basin irrigation without mulch as there was no investment incurred on drip and plastic mulch. However, treatment (T_8) can not be recommended as gross income and water use efficiency, both are very low as compared to other treatments. The Benefit-Cost ratio next in the order was treatment T_2 (VDM) followed by treatment T_4 (0.8 VDM). As application of plastic mulching and drip has increased the yield and from economical investment point of view, the treatment VDM should be recommended. However, when availability of water is the constraint then the treatment 0.8 VDM should be used.

Water use efficiency was also found to be highest as 6.71 kg ha^{-1} mm^{-1} for treatment T_4 (0.8 VDM). The lowest value of water use efficiency was found as 3.27 kg ha^{-1} mm^{-1} in treatment T_8 (VRB). Based on the water use efficiency and benefit:cost analysis the treatment T_4 can be recommended for sapota cultivation.

Summary

The daily water requirement of Sapota crop varies from 10.71 L/d to 34.43 L/d in different weeks. The maximum daily water requirement of 34.43 L during 30th April to 6th May should be used for design and planning purpose.

Application of plastic mulch alone increased the yield of crop which varies from 7.62% to 41% in different irrigation treatments. Yield of sapota crop was found to increase by 21.05% due to drip in comparison to ring basin irrigation.

The different amount of water application through drip alone or with plastic mulch has significant effect on the sapota fruit yield and quality. The study revealed increase in weight of fruit, volume, dimension, peel-pulp ratio with the increase in amount of irrigation water application through drip and plastic mulch. The pH value of fruit increases with decrease in amount of the irrigation water application. The TSS, total sugar, reducing sugar increases with decrease in amount of irrigation water application. Thus, the sweetness of the fruit has increased at reduced irrigation water application.

Income from the sapota crop due to plastic mulch was found to vary between ₹ 18000 (US$ 324) and ₹ 46000 (US$ 828) per hectare of land under different treatments under investigation. The income due to drip itself was found ₹ 20000 (US$ 360) per hectare of Sapota cultivation. Water use efficiency was found maximum for the treatment T_4 (0.8VDM) as 6.71 kg ha^{-1} mm^{-1}. Thus in terms of water use efficiency this treatment is the best among other treatments.

Acknowledgements

Authors are thankful to the National Committee on Plasticulture Applications in Horticulture (NCPAH), Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India for providing necessary funds and Department of Agricultural and Food Engineering, IIT Kharagpur, India for making available necessary facilities to conduct this research studies.

References

Allen, R.G., Pereira, L.S., Raes, D. and Smith, M., 1998. Crop evapotranspiration guidelines of computing crop water requirement. *Irrigation and Drainage Paper* **56:** FAO, Rome.

Bryla, D.R., Yorgey, B. and Shireman, A.D. 2009. Irrigation management effects on yield and fruit quality of highbush blueberry. *Acta Horticulturae* **810**: 649-656.

Cetin, O. and Uygan, D. 2008. The effect of drip line spacing, irrigation regimes and Planting geometries of tomato on yield, irrigation water use efficiency and net return. *Agricultural Water Management* **95**: 949-958.

Gontia, N.K. 2006. Crop water stress indices and evapotranspiration estimation. An unpublished Ph.D. thesis submitted to IIT Kharagpur, India.

Khattab, M.M., Shaban, A.E., Hussein, I., Elgamaal, O.H., 2009. Effect of Irrigation Levels on Fruit Quality of Picual Olive (*Olea europaea* L.) Cultivar. *Journal of Applied Sciences Research* **5**(10): 1552-1557.

Kulkarni, A.P., Policegoudra, R.S. and Aradhya, S.M., 2006. Chemical and antioxidant activity of Sapota (Achras Sapota LINN.) fruit. *Journal of Food Biochemistry* **31**: 399-414.

Kumar, K.S. 2010. Evaluation and simulation of greenhouse microclimate for subtropics. Unpublished Ph.D. thesis submitted to *Indian Institute of Technology*, Kharagpur, India.

Liu, M. and Wu, L.H., 2003. Study on changes of soil fertility in rainfed paddy soils with mulching plastic film. *Acta. Agriculture. Zhejiangensis* **15**(1): 8–12 (in Chinese, with English abstract).

Pattanaik, S.K., Sahu, N.N., Pradhan, P.C. and Mohanty, M.K. 2003. Response of Banana to Drip Irrigation under Different Irrigation Designs. *Journal of Agricultural Engineering* **40**(3): 29-34.

Proietti, P. and Antognozzi, E. 1996. Effect of irrigation on fruit quality of table olives {Olea europaea), cultivar 'Ascolana tenera'. *New Zealand Journal of Crop and Horticultural Science* **24**: 175-181.

Ramakrishna, A., Tam, H.M., Wani, S.P. and Long, T.D. 2006. Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. *Field Crops Research* **95**: 115–125.

Ranganna, S. 2001. Proximate constituents. In Handbook of Analysis and Quality Control for Fruit and Vegetable Products, 2nd Ed., Tata McGraw-Hill, New Delhi, India.

Rao, A.S. (ed.), 1994. Drip irrigation in India. Indian National Committee on Irrigation and Drainage, Ministry of water Resources, Government of India, p. 176.

Singh, B.K., Tiwari, K.N., Chourasia, S.K. and Mandal, S. 2007. Crop water requirement of Guava (*Psidium guavajava* L.) cv KG/KAJI under drip irrigation and plastic mulch. *Acta Horticulturae* **735**: 399-405.

Tiwari, K.N., Mal, P.K., Singh, R.M. and Chottopadhyay. A. 1998. Response of okra (*Abelmoschus esculentus* L.) to drip irrigation under mulch and non-mulch conditions. *Agricultural Water Management* **38**: 91-102.

Wu, L.H., Zhu, Z.R., Liang, Y. C., Shi, W.Y. and Zhang, L.M. 1999. A high-yielding, water-saving and fertilizer-saving cultivation technique for rice mulched by plastic film under dry land condition. *Journal of Zhejiang Agricultural University* **25**: 41–42 (in Chinese, with English abstract).