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Influence of Drip Irrigation and Plastic Mulch on Yield of Sapota (Achraszapota) and Soil Nutrients

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Abstract

The experiment was carried out to study the response of Sapota (Achraszapota) crop under drip irrigation and plastic mulch. Three levels of irrigation water applied through drip, ring basin irrigation method in combination with plastic mulch were experimented with five replications on Sapota plants. Reference evapotranspiration was estimated using FAO-56 Penman Monteith approach. The Sapota crop water requirement was estimated using reference evapotranspiration data and crop co-efficient for different crop growth stages. The irrigation water was applied at 60%, 80% and 100% of the crop water requirement. Irrigation intervals were at 2 and 5 days respectively in drip and ring basin irrigation treatments. The water requirement of Sapota crop varies between 2.14 mm (10.71 L) per day per plant in winter season and 6.89 mm (34.44 L) per day per plant in summer season for 100% water requirement treatment at peak growth stage. To investigate the effect of plastic mulch on soil, the physico-chemical analysis of soil was performed for the soil samples collected from three different depths (0-30, 30-60, 60-90 cm). The soil chemical analysis indicated increase in organic carbon, organic matter, humic acid, microbial count, available potassium, available phosphorus, total nitrogen content and C:N ratio for the soil covered with the plastic mulch treatment. The pH and available nitrogen was found to decrease in the soil covered with plastic mulch. The biometric observations (canopy, height, girth, no. of branches) of Sapota plants showed positive influence of the irrigation and plastic mulch treatments on growth of Sapota crop. Due to mulch alone the increase in Sapota yield varied from 7.62% to 41% in different treatments. Yield of Sapota crop was found to increase by 21.05% due to drip in comparison to ring basin irrigation.

Keywords: Sapota; Drip irrigation; Water requirement; Plastic mulching; Soil nutrient

Introduction

Optimum moisture level in the soil near the root zone of the crop is critical to agriculture and plantation crops. Drip irrigation is frequent application of water directly on or below the soil surface near the root zone of plants. Drip irrigation is one of the irrigation methods which can help to increase irrigation water potential and crop yield. Crops yield get adversely affected due to excess or deficit water supply. Crop yield can be considerably increased by optimal water supply. Drip irrigation can be helpful if water is scarce or expensive because evaporation, runoff, and deep percolation are reduced and irrigation application efficiency is improved. Strategically deficit water supply through drip irrigation can save 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 ensure equitable water distribution.

Drip irrigation in combination with plastic mulch research studies carried out at Precision Farming Development Centre, IIT Kharagpur, India on vegetable and fruit crops showed increase in yield, saving in water, higher water use efficiency and net increase in profit [1-3]. Growth and production of peach trees were monitored under furrow, surface and subsurface drip and micro jet irrigation systems for different irrigation scheduling. Higher water use efficiency, yield and larger trees growth were reported under surface and subsurface drip as compare to micro jet irrigation systems and furrow irrigation [4]. Saving in irrigation water and greater net profit due to drip irrigation in banana production has been reported by Kanannavar and Pawar [5,6]. Gunduz et al. [7] investigated the effect of amount of irrigation, irrigation interval using drip irrigation on yield and quality of peach. Amount of irrigation water application to peach crop was estimated using pan evaporation data with different pan coefficient. The amount of irrigation water application had significant influence on peach yield.

Mulch is a protective cover placed over the soil surface. Mulch can play an important role for sustainable fruit production. Beneficial aspects of plastic mulch include conservation of moisture, controls weeds and moderate soil temperature for better root growth and higher crop yield [8]. The use of plastic mulch alters soil temperature. Dark opaque plastic mulches and clear mulches applied over the soil intercept sunlight that warm the soil allowing earlier planting as well as encourage faster growth and early crop production. White mulch reflects solar radiation from the sun effectively reduces 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. Plastic mulches prevent sunlight from reaching the soil which can inhibit most annual and perennial weeds. Clear plastic mulch does not prevent weed growth as light passes through the film and reaches soil and weed plant. In black plastic mulch holes in the mulch for plants tend to be the only pathway for weeds to grow [9].

The use of drip irrigation in conjunction with plastic mulch allows conservation of water and fertilizers. Using drip irrigation for orchard crop eliminates the use of ring basin irrigation that applies large quantities of water to the soil which in turn tends to leach nitrogen and

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other nutrients to depths below the root zone. Drip irrigation applies lower amount of water with fertilizers frequently to the root zone as and when needed. This reduces the amount of fertilizer application as compared to broadcasted method of fertilization. Drip irrigation in combination with plastic mulch achieves additional benefits of water and fertilizer saving besides greater yield.

Sapota juice is good sources of sugar, proteins, ascorbic acid, phenolics, carotenoids and minerals like iron, copper, zinc, calcium and potassium [10].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 peel-pulp ratio increases with the optimum irrigation water supply as water availability influences cell division more than cell expansion but no influence on fruit shape [11].

Drip method of irrigation requires fixed capital investment for installation of drip system. The amount of investment depends upon the kinds of crop, its spacing, type and discharge capacity of the dripper and the distance from water source. Wide-spaced crops require relatively low capital cost. Besides capital investment there are investments such as operating cost, cost of fertilizer used, water used, skilled labors requirement, etc. It is very important for the Sapota crop growers to know the amount of money to be invested before cultivation of the crop. The investment made by the grower on the crop must get adequate profit to adopt drip and plastic mulch. The yield and quality of the crop produce should be high so as to overcome the investment made on the crop cultivation. Any new technology would be acceptable only if crop production give greater Benefit-Cost (B.C.) ratio.

In this research paper an attempt is made to study the response of combined effect of drip irrigation and plastic mulch with different levels of irrigation on Sapota crop grown in sub- humid and sub-tropical climate of Kharagpur. This study is also aimed to investigate influence of plastic mulch on soil properties and Sapota yield, kept above soil surface for long time.

Materials and Methods

Description of study area

The study area is located at Precision Farming Development Centre, experimental farm of 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 an 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 during winter and summer seasons respectively. The maximum and minimum relative humidity varies respectively from 79 to 99 % and 19 to 78 % throughout the year.

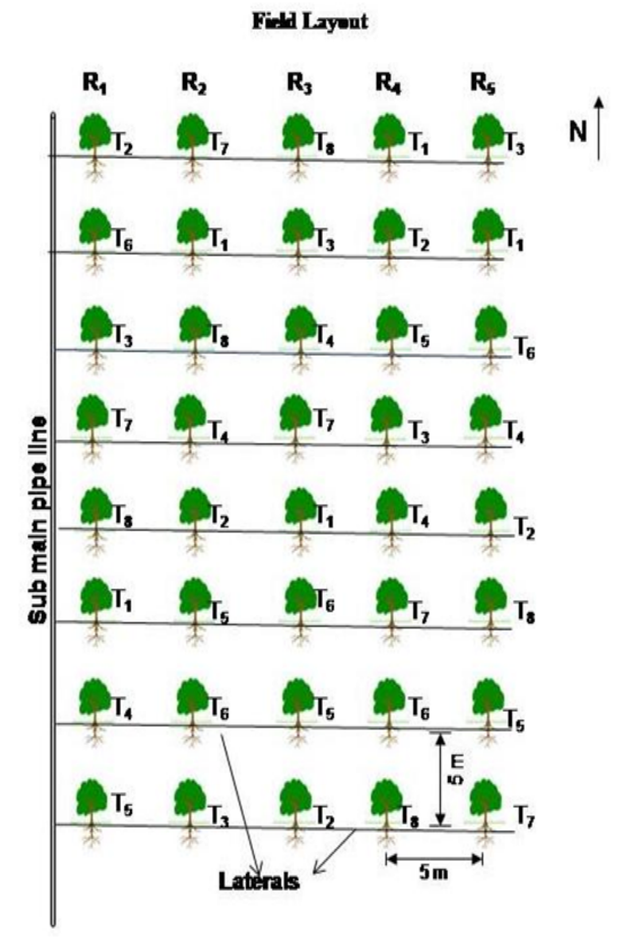
Crop details

Field experiments were conducted on Sapota crop belongs to Sapotaceae family Kalipatti variety. The crop was planted on 4th October 2005 in the PFDC farm which is now six years old. Being a tropical fruit crop it can be grown from sea level up to 1200 m above MSL. It needs warm (10-38°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. 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.

Field layout and experimental details

The experimental field of sapota is rectangular in shape with 40 m long and 25 m wide and plant to plant and row to row distance is 5m x 5m. There are total of forty numbers of plants in the field. The topography of the land area is plain and it has sandy-loam texture of soil. The total length of 12 mm dia lateral used in the field was 150 m with 70 drippers of different discharge combinations. The distribution of water in different lateral was controlled by 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 layout of the field and the division of plots along with the laterals fitted with drippers is shown in Figure 1.

The combination of different levels of irrigation with drip alone and drip with black plastic mulch ring basin with plastic and ring basin alone (control) were considered as treatments of experiment. Total eight treatments had eight rows with five plants in each row having different levels of irrigation water application.



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

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

The treatments followed for the study were as stated below:

T 1: 100% of irrigation requirement met through drip irrigation (VD)

T 2: 100% of irrigation requirement met through drip irrigation with plastic mulch (VDM)

T 3: 80% of irrigation requirement met through drip irrigation (0.8VD)

T 4: 80% of irrigation requirement met through drip irrigation with plastic mulch (0.8VDM)

T 5: 60% of irrigation requirement met through drip irrigation (0.6VD)

T 6: 60% of irrigation requirement met through drip with plastic mulch (0.6VDM)

T 7: 100% of irrigation requirement met through ring basin irrigation with plastic mulch (RBM)

T 8: 100% of irrigation requirement met through ring basin (RB)

Randomized block design was used to supply water to plants at different irrigation levels. The five of plants in each treatment were set randomly for irrigation either by drip irrigation or ring basin. Treatments T1 and T2 had combination of two drippers of 4 lph and one dripper of 2 lph discharge. Treatments T3 and T4 had two drippers of 4 lph discharge and Treatments T5 and T6 had combinations of one dripper of 4 lph and one dripper of 2 lph discharge.

Estimation of irrigation water requirement

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

$$WR = ET_o x K_c x W_p x A \quad (1)$$

Where,

WR = Crop water requirement (L d-1)

ETo = Reference evapotranspiration (mm d-1)

Kc = Crop coefficient

Wp = Wetting fraction

A = Plant area (m2)

Net irrigation water requirement was estimated by using Equation 2.

$$IR = ET_0 x Kc x W_p x A - \mathrm{Re}\, x W_p x A \quad (2)$$

Where,

IR=Net irrigation requirement (L d- 1)

Re=Effective rainfall (mm d- 1)

Daily reference evapotranspiration (ET0) was estimated using FAO-56 Penman Monteith Equation [2] and using estimated ET_0 values for Kharagpur by Singh [12] and Gontia [7]. The crop co-efficient for different growth stages were considered based on the available local studies from unpublished literature and similar crop information given in Allen [13]. Wetting per cent (Wp) was decided based on average canopy growth of the plant (which was 40 % of the area of each plant). As the canopy area increases the wetting fraction also increased [14]. In case of ring basin irrigation, the wetted area was more than the drip irrigation due to larger volume of water supply at 5 days interval. Rainfall occurred during non monsoon months (October-May) was considered as effective rainfall. Effective rainfall during monsoon months was estimated using the guidelines proposed by Doorenbos and Pruitt [15]. Irrigation during monsoon months (June-September) was given when dry spell exceeded more than 7 days.

The irrigation system was operated to meet the irrigation water requirement for plant under drip, ring basin, as well drip and ring basin with plastic mulch. The time of operation of the drip system was determined based on emitter discharge and volume of water to be delivered in different treatments. Two days irrigation interval was made for the plants under the treatments T1 to T6 in case of drip irrigation and for the irrigation treatments T7 and T8 (ring basin) water was applied in five days interval directly to the basin.

Measurement of biometric response of crop and analysis of physico-chemical properties of soil

Biometric observations on plant canopy diameter, height, girth and number of branches were measured 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.

The soil samples were collected from 0-30, 30-60 and 60-90 cm depths using screw auger from the experimental plots of Sapota crop for analyzing the physico-chemical properties of soil. The soil samples collected were kept for air drying and then it was grinded manually and passed through 2 mm sieve. Some selected chemical properties such as soil pH, carbon content, available nitrogen, available phosphorus and potassium content which have direct influence on the fertility status of soil were evaluated for all the treatments. The soil moisture content, bulk density and porosity of soils of different treatments were determined using standard methods.

Results and Discussion

Water requirement of sapota crop

Figure 2 shows average weekly variation in Crop EvapoTranspiration (ETc) for 52 weeks. The maximum weekly evapotranspiration was found as 21.26 mm for 18th week and minimum value as 6.62 mm in 51st week.

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 raises maximum during summer months and minimum during winter months. The maximum value of crop water requirement was found as 6.89 mm (34.44 L) per day in 18th week (May month) and minimum value as 2.14 mm (10.71 L) per day in 51st week (December month) for 100% crop water requirement. The irrigation water requirement supply varied as per the treatments i.e. 100%, 80 % and 60%.

Soil temperature

The soil temperature was measured at 15, 30 and 90 cm of soil depth both for the control (without mulch) and black plastic mulch (100μ). It can be seen from the observations presented in Table 1 that average temperature at 15 cm soil depth during winter season varied between 13.5°C to 27.5°C under control plot where as temperature varied between 15 to 31.5°C under black plastic mulch condition. During summer months (March to May) temperature at different depth ranged

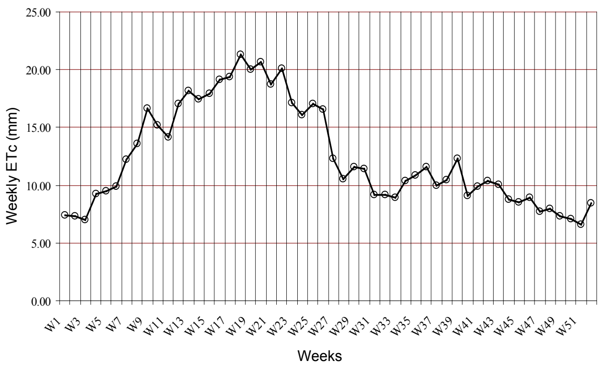


Figure 2: Average weekly evapotranspiration of Sapota crop (ETc).

from 14.5 to 32.5°C in control plot and 15 to 35°C under black plastic mulch. In general rise in the soil temperature was observed under plastic mulch condition. Increase in soil temperature has been reported under plastic mulch condition by Wu and coworkers [16]. They also reported faster growth of rice. Rise in the soil temperature during winter season under plastic mulch might have influenced for increase in the yield of Sapota crop due to increased activity of microorganisms which transforms nutrients. Soil treated with plastic mulch caused accumulation of more organic matter and humic acid which is the store house of plant nutrients that supplies nutrient to plant.

Biometric response of Sapota crop with drip irrigation and plastic mulch

Treatment-wise biometric observations of the crop were recorded from April 2006 to April 2011. Table 2 shows the pooled values of biometric attributes (canopy, height, girth and no. of branches) under different treatments.

From the Table 2, it is revealed that the drip irrigation with plastic mulch has the significant influence on plant growth and yield in comparison to basin irrigation (T7) and without mulch (T8). All the vegetative attributes and yield at 80% and 100% irrigation water requirement met with drip irrigation plastic mulch (T2 & T4) were statistically at par and non significant for canopy development. Results showed highest value of plant height, girth, number of primary branches under the treatment T2 and lowest under the treatment T8 except for number of primary branches under treatment T5.

The yield data presented in Table 2 and Figure 3 shows that the yield of Sapota crop was also statistically significant under different treatment combinations. The Sapota yield was found to decrease as the amount of irrigation water supply was reduced from 100 % to 60 % of irrigation requirement. Maximum yield of 16.1 t ha-1 was found in treatment T2. With the same level of irrigation water application between two treatments, the yield was always greater in case of plastic mulch treated plants. This could be due to greater nutrients and water availability to plants as compared to non mulched condition. These results are also supported by studies conducted on rice crop in China by Wu [16] and Liu Wu [17].

With 100 % irrigation water supply through drip system the yield of Sapota was estimated to be 21.05 % more than the conventional ring basin irrigation. This may be due to better soil water environment in root zone because of reduction in bulk density and greater porosity due to drip irrigation. With 20 per cent reduced irrigation water supply through drip, 17.89 per cent greater yield was found over conventional ring basin irrigation, with 40% reduced water supply through drip the yield was reduced marginally by 0.32 per cent over ring basin irrigation (RB), which is statistically at par. Hence in case of water scarcity the drip irrigation is a viable option to adopt.

Physico-chemical properties of soil

To study the effect of drip irrigation and plastic mulch on soil, the soil samples were collected from the experimental plots for evaluating the physical and chemical properties of the soil of the Sapota crop root zone. The treatment-wise average value of results of the analysis is shown in Table 3.

Table 3 shows the effect of drip irrigation and plastic mulch on bulk density and porosity of the surface soil (0-30 cm) of Sapota crop. From the analysis of the results it was revealed that the bulk density has reduced and porosity has increased in six years for all the plastic mulch treated soils having same amount of water application. The maximum value of bulk density and minimum value of porosity was found as 1.72 g/cm^3 and 35.1% respectively for plots with ring basin irrigation without mulch (T8). The minimum value of bulk density and maximum value of porosity was found as 1.59 g/cm^3 and 40.0% respectively for the plots within the drip irrigation and plastic mulch (T2). This analysis revealed that soil gets compacted due to surface sealing in basin irrigation where as plots with drip irrigation with plastic mulch, the bulk density was found to reduce and corresponding increase in the porosity Similar results are reported by Khan [18].

Table 4 shows the changes in the chemical properties of the soil samples collected from Sapota crop field due to different treatments. It is observed that soil has become acidic, pH of the surface soil (0-30 cm) ranged from 5.52 to 5.98. In the sub-surface soil (30-60 cm) pH ranged from 5.62 to 5.98 and in the subsoil (60-90 cm) it ranged from 5.94 to 6.27.

In natural condition, due to enzymatic oxidation carbon dioxide is evolved on soil surface but in mulch condition carbon dioxide evolution is restricted in soil. The accumulated carbon dioxide in soil reacts with soil moisture and formed carbonic acid. Therefore pH of soil covered with plastic mulch is marginally decreased compared to soil without plastic mulch. Soil pH value generally increased in subsoil as base material like Ca, Mg, Na, K, etc. leaches down to subsoil.

The organic carbon in surface soil (0-30 cm) was found to vary from 2.50 $g.kg^{-1}$ to 4.79 $g.kg^{-1}$. In sub surface soil it ranged from 0.66 $g.kg^{-1}$ to 1.73 $g.kg^{-1}$ and in subsoil (60-90 cm) it ranged from 0.48 $g.kg^{-1}$ to 1.24 $g.kg^{-1}$. The organic matter was found to vary from 4.31 to 8.25 $g.kg^{-1}$ in surface soil and further it was found to decrease in subsurface soil. In the mulched soil the organic carbon and organic matter content is preserved and found greater as compare to the non-mulched soils.

The statistical analysis revealed that drip irrigation treatments with and without mulch has significant influence on soil bulk density, organic carbon and soil pH. However at 60% water requirement met with drip and ring basin irrigation had no significant influence of plastic mulch on soil pH.

Table 5 shows the effect of plastic mulch on changes of available nutrients (N, P and K) and soil moisture. From the Table 5 it was also revealed that with the same volume of irrigation water applied to plants in treatments T1 and T2, the soil moisture content measured after two days of irrigation was found to be greater in the soil covered with plastic mulch. It is also found that the plastic mulch had greater

Season	Soil temperature in Control (°C)			Soil temperature in plastic mulch (°C)		
	15 cm	30 cm	90 cm	15 cm	30 cm	90 cm
Winter (Dec-Feb)	13.5-27.5	14.5-29.0	16.5-26.0	15.0-31.5	17.5-30.5	17.0-28.0
Summer (March-May)	17.0-30.5	14.5-30.5	17.5-32.5	16.5-35.0	15.0-32.0	17.5-33.5

Table 1: Temperature variation in control and plastic mulched plots at different soil depth.

Treatment	Plant height (m)	Girth (cm)	No. of primary branches	Canopy (East-West) (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 plastic mulch and drip irrigation on biometric attributes and Sapota yield.

Treatments	Bulk density (g/cm^3)	Porosity (%)
T_1 (VD)	1.69	36.2
T_2 (VDM)	1.59	40.0
T_3 (0.8VD)	1.71	35.4
T_4 (0.8VDM)	1.60	39.6
T_5 (0.6VD)	1.70	35.8
T_6 (0.6VDM)	1.61	39.2
T_7 (RBM)	1.65	37.7
T_8 (RB)	1.72	35.1

Table 3: Treatment-wise bulk density and porosity of surface soil (0-30 cm) of Sapota crop.

Treatments	Depth (cm)	pH	Organic carbon (g kg^{-1})	Organic matter (g kg^{-1})
T_1 (VD)	0-30	5.98	3.32	5.72
	30-60	5.99	0.66	1.14
	60-90	6.27	0.65	1.12
T_2 (VDM)	0-30	5.57	4.79	8.25
	30-60	5.62	1.40	2.41
	60-90	6.09	0.74	1.28
T_3 (0.8VD)	0-30	5.90	3.55	6.12
	30-60	5.92	1.73	2.98
	60-90	6.18	0.74	1.28
T_4 (0.8VDM)	0-30	5.6	4.38	7.55
	30-60	5.98	1.73	2.98
	60-90	6.27	1.24	2.14
T_5 (0.6VD)	0-30	5.69	3.81	6.57
	30-60	5.90	1.21	2.09
	60-90	5.98	0.55	0.95
T_6 (0.6VDM)	0-30	5.58	4.09	7.05
	30-60	5.79	1.15	1.98
	60-90	5.95	0.58	1.00
T_7 (RBM)	0-30	5.52	2.95	5.06
	30-60	5.69	1.01	1.74
	60-90	5.94	0.48	0.83
T_8 (RB)	0-30	5.64	2.50	4.31
	30-60	5.78	0.95	1.64
	60-90	6.02	0.52	0.90

Table 4: Effect of drip irrigation and plastic mulch treatments on chemical properties of soils of experimental plots with different treatments.

Treatment	Depth (cm)	Moisture content (%)	Available N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})
T_1 (VD)	0-30	11.62	80	52.7	75
	30-60	13.12	76	24.8	91.2
	60-90	14.95	68.5	17.6	112.5
T_2 (VDM)	0-30	13.10	78.5	77.8	85.7
	30-60	13.98	73	25.5	95.2
	60-90	14.98	49	22.5	118.4
T_3 (0.8VD)	0-30	11.23	91	22.8	68.7
	30-60	12.65	90	22.3	75.9
	60-90	14.76	80.5	2.7	102.5
T_4 (0.8VDM)	0-30	12.10	68.5	26.2	87.2
	30-60	13.45	66	14.9	90.5
	60-90	14.65	39.2	3.2	116.5
T_5 (0.6VD)	0-30	9.35	88	43.7	83.7
	30-60	11.11	64.3	25	97.5
	60-90	13.62	52.1	8.7	111.2
T_6 (0.6VDM)	0-30	10.55	81.6	52.2	85.7
	30-60	12.12	63	32.7	98.5
	60-90	13.44	47.5	11.6	110.7
T_7 (RBM)	0-30	10.45	44.0	18.4	80.7
	30-60	12.89	32.9	16.8	86.8
	60-90	13.40	32.1	15.2	100.6
T_8 (RB)	0-30	8.90	55.9	17.3	62.5
	30-60	11.23	43.8	15.8	75.2
	60-90	13.34	25.9	10.2	88.7

Table 5: Effect of drip and plastic mulch treatments on soil moisture content and available soil nutrients (N, P, K) at different soil depths.

Treatment	Organic carbon (g kg^{-1})	Total nitrogen (g kg^{-1})	C:N ratio	Humic acid (g kg^{-1})	Total microbial count (cfu/g)
T_1 (VD)	3.32	0.37	8.9:1	0.46	35 x 10^4
T_2 (VDM)	4.79	0.45	10.6:1	1.20	25 x 10^5
T_3 (0.8VD)	3.55	0.41	8.6:1	0.80	5 x 10^5
T_4 (0.8VDM)	4.38	0.46	9.5:1	1.32	6 x 10^5
T_5 (0.6VD)	3.81	0.42	9.1:1	0.62	15 x 10^4
T_6 (0.6VDM)	4.09	0.44	9.3:1	0.72	16 x 10^4
T_7 (RBM)	2.95	0.36	8.3:1	0.42	12 x 10^4
T_8 (RB)	2.50	0.33	7.6:1	0.38	20 x 10^3

Table 6: Effect of drip irrigation and plastic mulch treatments on total nitrogen and C:N ratio in surface soil (0-30 cm).

influence on conserving moisture content of surface soil (0-30 cm) than the subsurface soil. Similar trend was found for other treatments. This may be due to the fact that plastic mulch prevents water to evaporate and conserves moisture within the soil.

The available nitrogen content in surface soil (0-30 cm) was found to vary between 44 mg.kg^{-1} and 91 mg.kg^{-1}. In subsurface soil (30-60 cm) it varied from 32.9 mg.kg^{-1} to 91 mg.kg^{-1} and in subsoil (60-90 cm) from 25.9 mg.kg^{-1} to 80.5 mg.kg^{-1}. In plastic mulched soil, nitrogen mineralization is restricted due to lack of exchange of gases like oxygen for micro-organisms with the evolution of carbon dioxide. It seems soil covered with the plastic mulch contains less available nitrogen for plant compared to soil without plastic mulch.

The treatment with plastic mulch was found to contain more available phosphorous for plant compare to non mulched soils. Surface soil contained more available phosphorous than subsurface soil. The maximum available phosphorous in surface soil was found to contain 77.8 mg.kg^{-1} in treatment T2 where as in treatment T8 it was found to be minimum as 17.3 mg.kg^{-1}. Available phosphorous in water soluble and exchangeable form could be more in 100% of irrigation requirement met through drip in comparison to ring basin irrigation it is expected that Al, Fe and Mn will be more available in ring basin irrigation treatment (T8) which makes complexes with these metals.

The plastic mulched soil was found to contain more available potassium for the Sapota plants compared to plants grown in bare soil (without plastic mulch). Subsoil had more available potassium than surface soil as available potassium for plant generally leached down to subsoil horizon. Maximum value in surface soil was found as 87.2 mg.kg^{-1} in treatment T4 and minimum value as 62.5 mg.kg^{-1} in treatment T8. Due to leaching the potassium in subsoil increased to 118.4 mg.kg^{-1} in treatment T2 and minimum as 88.7 mg.kg^{-1} in treatment T8. This results in consistent with other research studies [19,20]. The increase in soil available P and K content may be due to greater temperature in mulched soil. It is hypothesized that plastic mulch might have changed soil moisture content and aeration conditions, which in turn resulted in the changes of soil microbial communities and redox potential, thus affected the soil phosphorus status.

Table 6 shows the effect of drip irrigation and plastic mulch on changes in organic carbon and total nitrogen in surface soil (0-30 cm). From the chemical analysis it was revealed that the carbon and total nitrogen percentage contents were greater in black plastic mulch

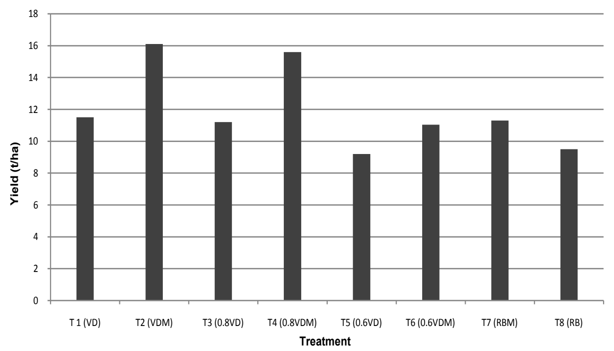


Figure 3: Yield of the sapota crop in different treatments.

treated plots compared to non-mulch. The maximum value of total nitrogen was found as 0.46 g.kg^{-1} in treatment T4 (0.8VDM) and minimum as 0.33 g.kg^{-1} in treatment T8 (RB). Range of C:N ratio in the surface soil was found to vary between 7.6:1 and 10.6:1. The availability of nitrogen to plant was observed highest in the treatment T2 followed by treatment T4 as 10.6 and 9.5 respectively and relatively lower in rest of the treatments. Higher C:N ratio for plant growth was observed in soil covered with black plastic mulch compared to non-mulch. The C:N ratio availability for growth of the plant was estimated to be normal in all the treatments. The C:N ratio of the organic material added to the soil influenced the rate of decomposition of organic matter and this results in the release (mineralization) or immobilization of soil nitrogen. If the added organic material contains more nitrogen in proportion to the carbon, then nitrogen is released into the soil from the decomposing organic material. On the other hand, if the organic material has a less amount of nitrogen in relation to the carbon then the microorganisms will utilize the soil nitrogen for further decomposition and the soil nitrogen will be immobilized and will not be available to plants.

The humic acid concentration was always found greater in the mulched soil than without mulch. Maximum humic acid concentration was found as 1.32 g.kg^{-1} in treatment T4 and lowest as 0.38 g.kg^{-1} in treatment T8. Humic acid in soil is amorphous dark brown color lignin and protein body of enzyme complexes. These enzymes remaining in microbial cell transform nutrient in ionic form and exchange by the plant root. Humus is known as store house of crop plant nutrient. The plants with drip irrigation and black plastic mulch check loss of carbon and carbon dioxide from soil. Carbon in lignin with protein body of enzyme in microbial cell which make complexes of humic acid this is expected to contain higher in plastic mulched soil with and drip irrigation due to optimum moisture content as compared to without mulch and surface irrigation.

The total microbial count was found to be greater in the plastic mulched soil than the soil without mulch. Maximum microbial count was found as 25 x 105 cuf/gm in the plants for treatment T2 and lowest as 20 x 103 cfu/gm in treatment T8, which shows that plastic mulched soil with drip irrigation increases the microbial activities in the soil.

Table 7 shows the N, P, K concentration in Sapota plant leaf. Nitrogen content in Sapota plant was always greater in mulch treated plants compared to without mulch. Highest concentration of nitrogen in leaf sample was found as 1.407 per cent in treatment T4, whereas lowest as 1.260 per cent in treatment T8.

Phosphorous content in Sapota plant was greater in plastic mulched treatments compare to without mulch. Highest concentration of phosphorous in Sapota leaf was found as 0.0648 per cent in the treatment T6 and lowest in treatment T8 as 0.0383 per cent.

Potassium content in Sapota plant leaf was also greater in mulch treated plants compared to without mulch. Highest concentration of potassium was found as 0.78 per cent in treatment T2 and lowest as 0.53 per cent in treatment T8.

From above analysis of results, it revealed that phosphorous and potassium content was higher in mulched plants which may be due to accumulation of more organic matter and humic acid. Black plastic mulch enhances soil temperature due to restricted Co_2evolution from soil surface. Increased temperature of soil solution the nutrient concentration like P & K also increased in the root zone. The basal ATPase and P & K activities in the presence of K+ were related with the root levels of thiscations. Similar results are also reported by Ruiz [12]. Soil temperature and moisture remain at optimum level under black plastic mulch condition during winter season. During winter the plant metabolism reduces that causes low uptake of P. The available soils P remain in the soil for residual use. This is more under mulch condition. Similar results are reported by Almeida [21].

Water use efficiency was found maximum for treatment T4 as 6.71 kg.ha^{-1}mm^{-1} containing drip irrigation and plastic mulch in which 80% irrigation water was met through drip. The lowest value of water use efficiency was found in treatment T8 as 3.27 kg.ha^{-1}mm^{-1} in which 100% water requirement was met through ring basin irrigation method. In ring basin irrigation there is huge loss of water is found in terms of evaporation, deep percolation, seepage loss, etc which lead to less water use efficiency than irrigation methods like drip and sprinkler.

Economic analysis of the project was carried out to determine the economic feasibility of using drip irrigation and plastic mulch in cultivation of Sapota crop. It allow us to compare different treatments containing drip only, drip with plastic mulch, ring basin with mulch, and ring basin alone. For this purpose costs for installation cost of drip, cost of mulching, labour cost, cost of fertilizer applied, cost on water and electricity, etc are considered. Based on present study all these costs and benefits obtained were taken annually and for one hectare of land. The economic analysis of different treatment in terms of Benefit-Cost ratio revealed that highest Benefit-Cost ratio was 3.59 for the treatment T2 (100% VDM) followed by 3.55 for the treatment T4 (80% VDM). The lowest benefit cost ratio of 1.84 was found under the treatment T8 (Ring Basin irrigation without mulch).

Conclusions

The maximum daily water requirement of the Sapota plant was estimated as 6.89 mm during 30th April to 6th May (18th week) and minimum as 2.14 mm in winter season during 17 to 23 December (51st week).

Treatment	N (%)	P (%)	K (%)
T_1 (VD)	1.092	0.0590	0.77
T_2 (VDM)	1.365	0.0640	0.78
T_3 (0.8VD)	1.386	0.0455	0.66
T_4 (0.8VDM)	1.407	0.0465	0.70
T_5 (0.6VD)	1.302	0.0460	0.73
T_6 (0.6VDM)	1.318	0.0648	0.76
T_7 (RBM)	1.302	0.0425	0.59
T_8 (RB)	1.260	0.0383	0.53

Table 7: Concentration of N, P, K in Sapota leaf.

Due to surface covering water is not able to escape therefore plastic mulch treatment conserved about 17.41% greater soil moisture than without mulch. Soils covered with plastic mulch and drip irrigation was found to remain soft and well aerated which is favorable for plant growth. The porosity of soil was found to be enhanced by 4.2% due to plastic mulch. The pH value of the soil covered with plastic mulch marginally decreased due to formation of carbonic acid. Organic carbon in surface soil due to plastic mulch was found to increase from 7.35 to 44.27 % in different irrigation levels and the similar trend was observed for organic matter content in the soil. Available potassium increased to vary between 2.39% and 26.9% and available phosphorus content increased to vary between 14.91% and 47.62% in soil covered with plastic mulch as compared to non mulced soil. Available nitrogen in mineralized form was generally found to decrease from 7.27% to 24.72% in soil covered with black plastic mulch as compared to bare soil due to depletion of oxygen for normal functioning of micro-organism. Total nitrogen content was found to be increased from 4.76% to 21.62% in plastic mulched soils than without mulch. It revealed that due to slow mineralization the release of nitrogen is restricted in soil covered with plastic mulch which reduces the wastage of nitrogen thereby it can be used in sustainable manner. Hence, C:N ratio was found good in plastic mulched soil than non-mulched soil. Humic acid and microbial counts were found greater in plastic mulch treated plots. Evolution of carbon dioxide from soil surface is restricted and leaching loss of nutrients is checked due to rainfall in mulched treated plots. In long duration crop like Sapota the black plastic mulch cover on soil causes cumulative accumulations of the slow organic matter from structural carbon with high lignin and plant nutrients conserve organic matter. So nutrients supplies to plant in slowly available form in sustainable manner for longer period. The analysis of N, P, K concentration in Sapota plant leaf was estimated to be more in soil plastic mulched plots than non-mulched plots. The yield of Sapota crop was found to be increased which varies from 7.62% to 41% in different irrigation treatments with plastic mulch. Yield of Sapota crop was found to increase by 21.05% due to drip in comparison of ring basin irrigation.

This study shows that the drip irrigation in combination of plastic mulch enhances Sapota yield and improves soil properties.

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