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Effect of Different Irrigation Levels and Mulching Methods on Performance of Organically Cultivated and Drip Irrigated Papaya

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted at research field of Deendayal Upadhyay Centre of Excellence for Organic Farming, CCS HAU, Hisar during the year 2021-22 to study the effect of different irrigation levels and mulching methods on performance of organically cultivated and drip irrigated papaya. The experiment comprised of nine treatments three different irrigation levels viz. 50%, 75% and

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100% of crop water requirement and three mulching methods. The results showed that the plant height (238 cm), stem girth (45.93 cm), crown diameter (242.67 cm), number of fruits (42.33), yield per plant (53.80 kg) and total yield (134.50 t ha$^{-1)}$ were observed maximum for meeting 100% of crop water requirement with the application of straw mulch and minimum for meeting 50% of crop water requirement without mulch condition. The soil moisture was found maximum for meeting 100% of crop water requirement with the application of plastic mulch minimum for meeting 50 % of crop water requirement without mulch condition. From the results, it is also observed that the irrigation water use efficiency (59.02 kg m^{-3}) was found maximum for meeting 50 % of crop water requirement with straw mulch and minimum (42.64 kg m^{-3}) for meeting 100% of crop water requirement without mulch under drip irrigation system.

Keywords: Irrigation levels; mulching; crop water requirement; papaya; crop yield; water use efficiency.

1. INTRODUCTION

Papaya (*Carica papaya* L.), a tropical fruit of the Caricaceae family, is grown commercially in tropical and subtropical areas. It requires well-drained or sandy loam soil with suitable organic matter, an optimum temperature of 25-30°C, and a minimum of 16°C. The ideal pH level for papaya cultivation is between 6 and 6.5. Papaya is a profitable crop that only bears fruit once a year and requires less space than bananas [1]. Papaya is largely grown in India, Myanmar, Sri Lanka, Puerto Rico, Texas, Florida, Taiwan, Brazil, Hawaii, Kenya, Australia, Malaysia, California, Burma and South Africa. India is the world's fourth-largest producer of papaya. It is successfully grown throughout India and available round the year. In India, it occupies 1.80% of total fruit crop land and contributes 6.30% of total fruit yield, with an average yield per hectare of 42.3 tonnes [2].

Mulching is an essential element of precision farming and considered as one of the most effective techniques a farmer can employ to maintain his land healthy. Mulching is a method of covering the soil surface with organic or synthetic mulch around plants in order to create favourable conditions for plant growth and efficient crop production [3,4]. Mulches regulate soil temperature, prevent soil moisture loss, protect soil from erosion, improve soil structure, reduce soil salinity, increase water infiltration rate by creating obstructions in the flow of water, decrease pest and disease populations, and promote microbial activity in the field. These are important variables that boost plant growth [5] and fruit yield [6,7].

Effective irrigation management is required to maximize production per unit of water consumed [8]. Under suitable conditions, drip irrigation is considered to be one of the most effective water-saving irrigation techniques because it precisely controls the amount of irrigation and only irrigates the root zone, increasing irrigation water productivity (WP) by lowering percolation and evaporation losses [9].

Papaya is also suited to drip irrigation in combination with straw and plastic mulch, but little work has been done to study the effects of different irrigation levels and mulching methods on crop yield and yield component of papaya in Haryana. The present investigation was planned to determine the effects of different irrigation levels and mulching methods on the performance of organically cultivated papaya.

2. MATERIALS AND METHODS

The present investigation was conducted at the field of Deendayal Upadhyay Centre of Excellence for Organic Farming, CCS Haryana Agricultural University, Hisar with a drip irrigation system during 2021-22. The experimental site is located in the north-western part of Haryana at $29^0$08'09.3" N (latitude) and $75^0$42'16.0" E (longitude) with an average elevation of about 215.2 m above the mean sea level (MSL). The Red lady variety of papaya was selected and obtained from the Centre of Excellence for Fruits, Mangiana, Sirsa. 45 days old seedlings of papaya were transplanted at spacing of 2 m X 2 m on 3rd March, 2021. After transplanting, first irrigation was applied same day in all the plants, through drip irrigation, for duration sufficient enough to ensure moisture for proper establishment of the crop. The present investigation was laid out in Split plot design with nine treatments combinations (three irrigation levels and three mulching methods) and three replications. The different treatments combinations of irrigation levels and mulching methods are presented in Table 1.

2.1 Irrigation Levels

I100 - 100 % of crop water requirement
I75 - 75 % of crop crop water requirement
I50 - 50 % of crop crop water requirement

2.2 Mulching Methods

SM - 10 cm thick straw mulch in one-meter diameter around the plant
PM - Plastic mulch in two-meter diameter around the plant
NM - No mulch

The experimental field was irrigated as per water requirement of the crop by using drip irrigation system. Crop water requirement was estimated with the help of meteorological data recorded by Department of Agricultural Meteorology, COA, CCS Haryana Agricultural University, Hisar. Previous two days pan evaporation data was used to calculate the crop water requirement to be applied on alternate days via drip irrigation system. The amount of irrigation water to be applied was determined as under [10].

$$V = \frac{W_a \times PE \times P_C \times K_C}{EU}$$

Where,

V = amount of water applied (L plant^{-1})
W_a = Wetted area
PE = sum of pan evaporation of last two days (mm)
P_C = pan coefficient (0.7)
K_C = crop coefficient of papaya [11]
EU = Emission uniformity of the system (considered as 90%)

Duration of the irrigation was calculated by [10]:

$$\text{Irrigation time (h)} = \frac{V}{Q}$$

Where, Q = Dripper discharge in L h^{-1}

For determination of physical and chemical properties of the experimental soil, the soil samples were collected from five randomly selected spots at 0-15 cm depth with the help of tube auger in the field and made a composite sample for initial analysis. Various physical and chemical properties of soil were observed with their standard analytical method and references of literature, as given in Table 2.

The plant growth and yield parameters such as plant height stem girth, crown diameter, number of fruits, yield per plant, yield per hectare and irrigation water use efficiency were measured at the time of harvesting and OPSTAT software [18] was used to analyse the collected data for statistical significance using the split plot design [19].

Table 1. Different treatment combinations of irrigation levels and mulching methods

Sr. no.	Irrigation levels	Mulching methods	Symbol
1	100 % of	Plastic mulch	I_{100}PM
2	crop water	Straw mulch	I_{100}SM
3	requirement	No mulch	I_{100}NM
4	75 % of crop	Plastic mulch	I_{75}PM
5	water	Straw mulch	I_{75}SM
6	requirement	No mulch	I_{75}NM
7	50 % of crop	Plastic mulch	I_{50}PM
8	water	Straw mulch	I_{50}SM
9	requirement	No mulch	I_{50}NM

3. RESULTS AND DISCUSSION

3.1 Soil Moisture Content

The soil moisture content of the soil was determined using the gravimetric method at 90, 120 and 150 days after transplanting (DAT) is presented in Table 3. Soil samples were collected at 30 cm away from the plant using a tube auger and at a depth of 0-30 cm below the soil surface. The soil moisture content was recorded maximum (17.32, 18.54 and 19.94 %) for I_{100}PM and minimum (9.11, 10.18 and 10.58 %) for I_{50}NM at 90, 120 and 150 days after transplanting (DAT), respectively.

Maximum average soil moisture content was found for I_{100}, followed by I_{75} and minimum average soil moisture content was found for I_{50} at 90, 120 and 150 DAT. This might be due to the fact that with increase in irrigation levels there was an increase in availability of soil moisture in soil profile and it resulted in higher soil moisture for I_{100} treatments than I_{75} and I_{50} treatments. This result was in conformity with the report of [20].

Soil moisture content was found higher in plastic mulched treatments (PM), followed by straw mulched treatments (SM) and lower in no mulched (NM) treatments. Relatively higher soil moisture content in the mulched treatments may be due to reduced evaporation losses from soil surface. However, there was little difference in soil moisture content between plastic mulched treatments and straw mulched treatments. This might be due to the fact that plastic mulches are completely impermeable to water, preventing the

Table 2. Physical and chemical properties of the soil before the experimentation

Parameters	Experimental value	Method of analysis
Texture	Sandy loam	[12]
pH	7.65	[13]
$EC_{1:2}$ (dS m^{-1})	0.37	
Available N (kg ha^{-1})	161	[14]
Available P (kg ha^{-1})	13	[15]
Available K (kg ha^{-1})	266.5	[16]
Soil organic carbon (%)	0.70	[17]

Table 3. Soil moisture content for different treatments observed at 90, 120 and 150 DAT

Sr. no.	Irrigation levels	Mulching methods	90 DAT	120 DAT	150 DAT
1	I_{50}	SM	11.41	11.77	12.47
2		PM	12.32	12.47	13.23
3		NM	9.11	10.18	10.58
4	I_{75}	SM	14.5	14.88	15.73
5		PM	15.04	15.32	16.41
6		NM	12.5	12.67	13.69
7	I_{100}	SM	16.52	17.07	18.87
8		PM	17.32	18.54	19.94
9		NM	15.09	15.61	16.58

direct evaporation of moisture from the soil and lowering water losses over the surface while straw mulches are semi impermeable to water [21].

3.2 Growth Parameters

3.2.1 Plant height (cm)

The combined effect of irrigation levels and mulching methods on average plant height was found statistically non-significant but average plant height was found maximum (238 cm) for treatment I_{100}SM and minimum (186.27 cm) for treatment I_{50}NM at the time of harvesting. The combined effect of irrigation levels and mulching methods on average plant height at harvesting is shown in Fig. 1. The effect of irrigation levels on average plant height was found statistically significant and maximum average plant height was found for I_{100} (230.65 cm), followed by I_{75} (213.47 cm) and minimum average plant height was found for I_{50} (191.81 cm) at the time of harvesting. The effect of mulching methods on average plant height was found statistically significant. The maximum average plant height was found for SM (220.66 cm), followed by PM (208.07 cm) and minimum for NM (207.20 cm) at the time of harvesting.

3.2.2 Stem girth (cm)

The combined effect of irrigation levels and mulching methods on average stem girth was found statistically non-significant but average stem girth was found maximum (45.93 cm) for treatment I_{100}SM and minimum (32.97 cm) for treatment I_{50}NM at the time of harvesting. The combined effect of irrigation levels and mulching methods on average stem girth at harvesting is shown in Fig. 2. The effect of irrigation levels on average stem girth was found statistically significant and maximum average stem girth was found for I_{100} (43.80 cm), followed by I_{75} (39.6 cm) and minimum average stem girth was found for I_{50} (34.52 cm) at the time of harvesting. The effect of mulching methods on average stem girth was found statistically significant. The maximum average stem girth was found for SM (41.41 cm), followed by PM (38.52 cm) and minimum for NM (37.99 cm) at the time of harvesting.

3.2.3 Crown diameter (cm)

The combined effect of irrigation levels and mulching methods on average crown diameter was found statistically non-significant but average crown diameter was found maximum (242.67 cm) for treatment I_{100}SM and minimum (190.93 cm) for treatment I_{50}NM at the time of harvesting. The combined effect of irrigation levels and mulching methods on average crown diameter at harvesting is shown in Fig. 3. The effect of irrigation levels on average crown diameter was found statistically significant and maximum average crown diameter was found for I_{100} (235.11 cm), followed by I_{75} (218.13 cm) and minimum average crown diameter was found for

I_{50} (196.42 cm) at the time of harvesting. The effect of mulching methods on average crown diameter was found statistically significant. The maximum average crown diameter was found for SM (225.32 cm), followed by PM (212.68 cm) and minimum for NM (211.87 cm) at the time of harvesting.

3.3 Yield Parameters

3.3.1 Number of fruits

The combined effect of irrigation levels and mulching methods on average number of fruits was found statistically non-significant but average number of fruits was found maximum (42.33) for treatment I_{100}SM and minimum (32.33) for treatment I_{50}NM at the time of harvesting. The combined effect of irrigation levels and mulching methods on average number of fruits at harvesting is shown in Fig. 4. The effect of irrigation levels on average number of fruits was found statistically significant and maximum average number of fruits was found for I_{100} (41), followed by I_{75} (37) and minimum average number of fruits was found for I_{50} (33.33) at the time of harvesting. The effect of mulching methods on average number of fruits was found statistically significant. The maximum average number of fruits was found for SM (38.44), followed by PM (36.78) and minimum for NM (36.11) at the time of harvesting.

3.3.2 Yield per plant (kg)

The combined effect of irrigation levels and mulching methods on average yield per plant was found statistically non-significant but

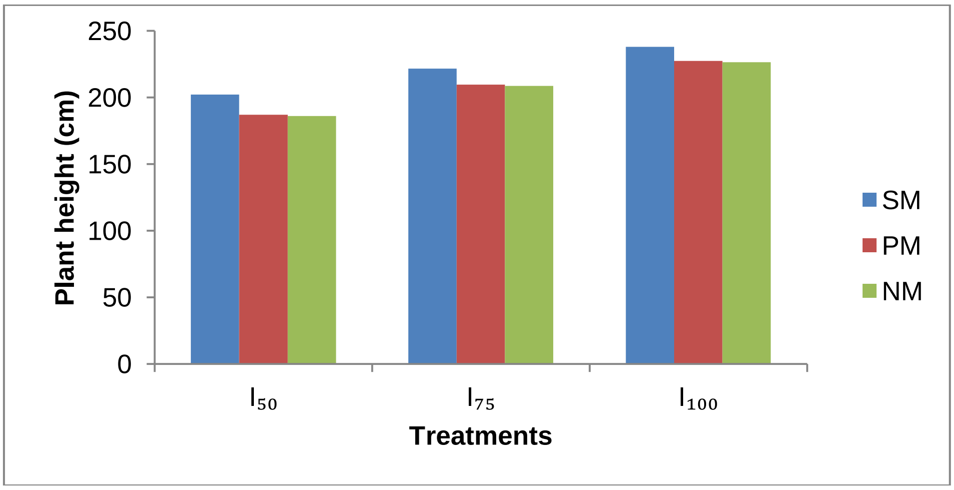

Fig. 1. Average plant height of papaya for different treatment combinations at harvesting

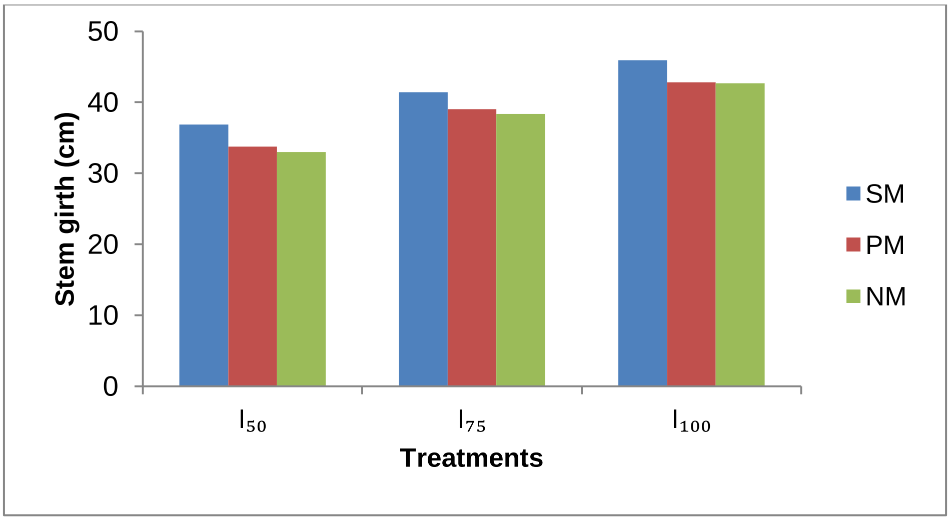

Fig. 2. Average stem girth of papaya for different treatment combinations at harvesting

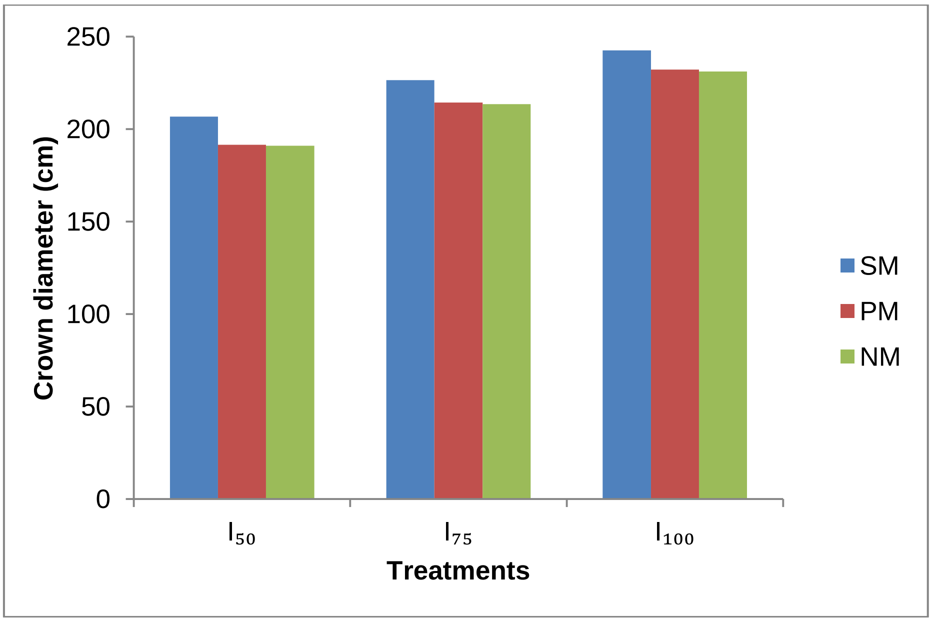

Fig. 3. Average crown diameter of papaya for different treatment combinations at harvesting

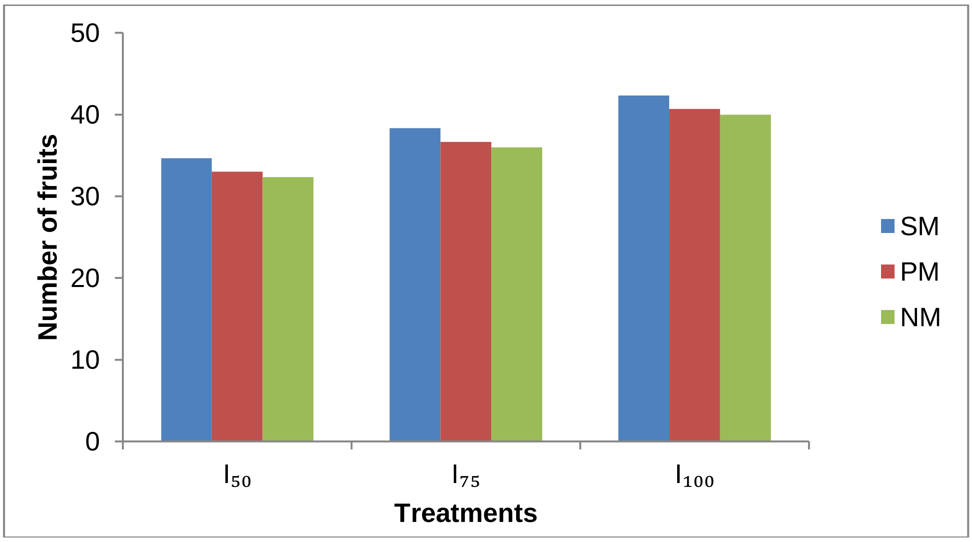

Fig. 4. Average number of fruits for different treatment combinations at harvesting

average yield per plant was found maximum (53.80 kg) for treatment I_{100}SM and minimum (35.83 kg) for treatment I_{50}NM at the time of harvesting. The combined effect of irrigation levels and mulching methods on average yield per plant at harvesting is shown in Fig. 5. The effect of irrigation levels on average yield per plant was found statistically significant and maximum average yield per plant was found for I_{100} (51.56 kg), followed by I_{75} (44.47 kg) and minimum average yield per plant was found for I_{50} (36.98 kg) at the time of harvesting. The effect of mulching methods on average yield per plant was found statistically significant. The maximum average yield per plant was found for SM (46.46 kg), followed by PM (43.52 kg) and minimum for NM (43.02 kg) at the time of harvesting.

3.3.3 Yield (t ha^{-1})

The combined effect of irrigation levels and mulching methods on average yield per hectare was found statistically non-significant but average yield per hectare was found maximum (134.50 t ha^{-1}) for treatment I_{100}SM and minimum (89.58 t ha^{-1}) for treatment I_{50}NM at the time of harvesting. The combined effect of irrigation levels and mulching methods on average yield per hectare at harvesting is shown in Fig. 6. The effect of irrigation levels on average yield per hectare was found statistically significant and maximum average yield per hectare was found for I_{100} (128.88 t ha^{-1}), followed by I_{75} (111.16 t ha^{-1}) and minimum average yield per hectare was found for I_{50} (92.44 t ha^{-1}) at the time of harvesting. The effect of mulching methods on average yield per hectare was found statistically significant. The maximum average yield per hectare was found for SM (116.13 t ha^{-1}), followed by PM (108.80 t ha^{-1}) and minimum for NM (107.56 t ha^{-1}) at the time of harvesting.

The effect of irrigation levels on plant growth and yield parameters was found statistically significant and these parameters were found for I_{100} and minimum for I_{50}. This might be due to the fact that with increase in irrigation levels there was an increase in availability of soil moisture in soil profile for plants and it resulted in higher average fruit yield for I_{100} treatment than I_{75} and I_{50} treatments. Similar results were reported by Lal, et al. [22].

The effect of mulching methods on plant growth and yield parameters was found statistically significant. The plant growth and yield parameters were found maximum for SM, followed by PM and minimum for NM. This might be due to fact that the presence of mulch at the soil surface resulted in relatively less evaporation losses which ensured better soil moisture availability in mulched treatments as compared to non mulched treatments. The plant growth and yield parameters of straw mulched treatments

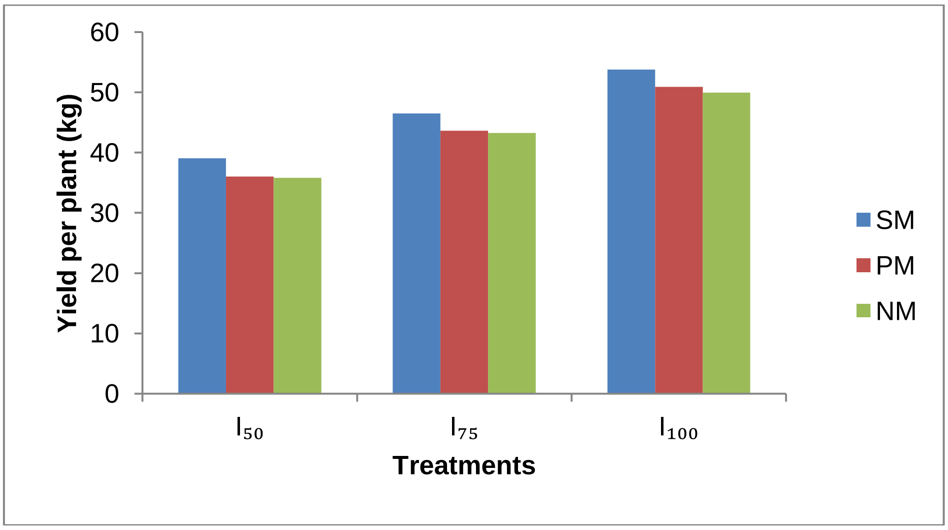

Fig. 5. Average yield per plant for different treatment combinations

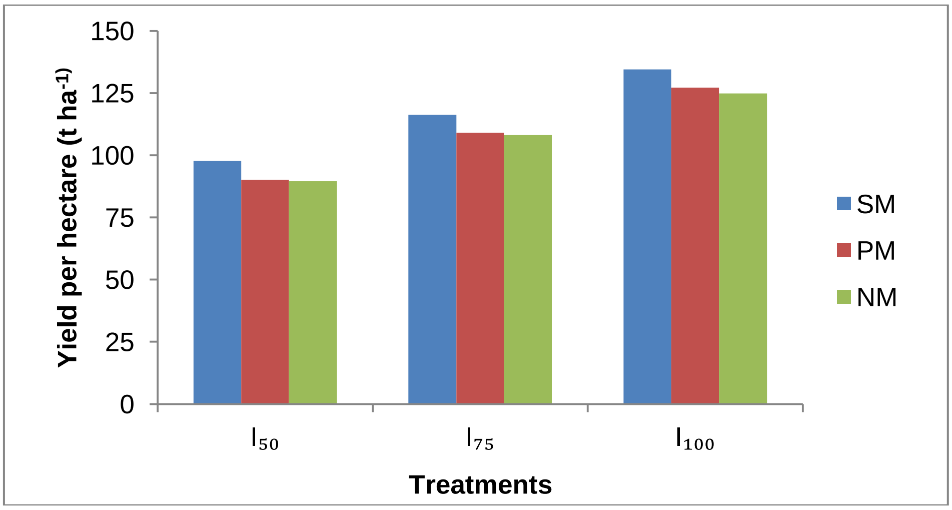

Fig. 6. Average yield per hectare for different treatment combinations

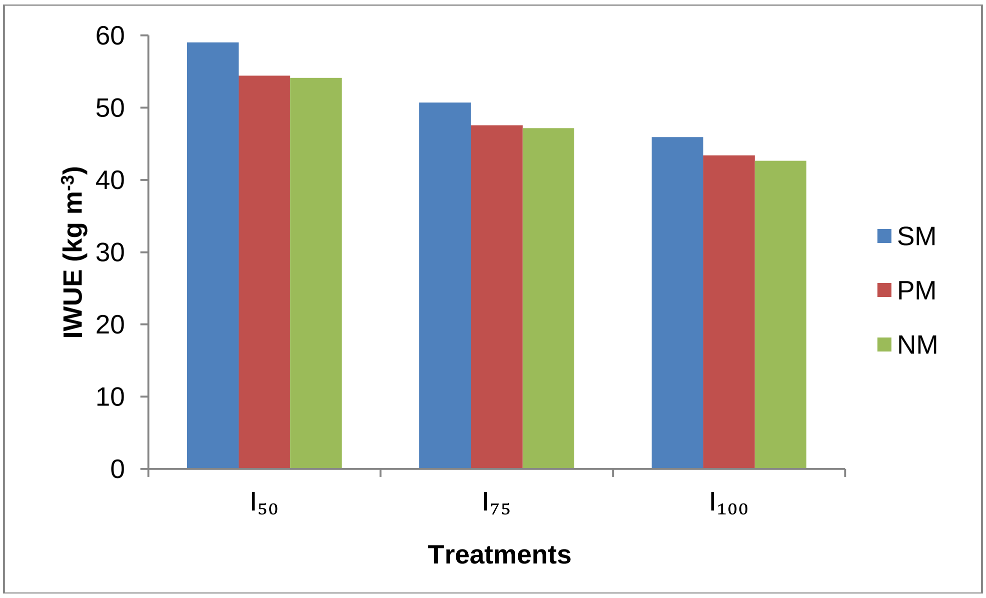

Fig. 7. Irrigation water use efficiency for different treatment combinations

(SM) found significantly higher than non mulched treatments as well as plastic mulched treatment (PM). Though comparable moisture content was available in root zone in straw mulched treatments and plastic mulched treatments but still straw mulched treatments out performs better than plastic mulched treatments. This might be possibly due to proper aeration, optimum soil temperature and favourable micro climatic condition beneath the straw mulch layers as compared to the plastic mulch layers. Similar results were reported by Nandhini et al. [23] on guava.

3.4 Irrigation Water Use Efficiency

The combined effect of irrigation levels and mulching methods on average irrigation water use efficiency was found statistically non-significant but average irrigation water use efficiency was found maximum (59.02 kg m^{-3}) for treatment I_{50}SM and minimum (42.64 kg m^{-3}) for treatment I_{100}NM. The combined effect of irrigation levels and mulching methods on average irrigation water use efficiency at harvesting is shown in Fig. 7.

The effect of mulching methods on average irrigation water use efficiency was found statistically significant. The maximum average irrigation water use efficiency was found for SM (51.88 kg m^{-3}), followed by PM (48.49 kg m^{-3}) and minimum for NM (47.99 kg m^{-3}).

The effect of irrigation levels on average irrigation water use efficiency was found statistically significant and maximum average irrigation water use efficiency was found for I_{50} (55.87 kg m^{-3}), followed by I_{75} (48.50 kg m^{-3}) and minimum average irrigation water use efficiency was found for I_{100} (43.99 kg m^{-3}) at the time of harvesting. Similar results were reported by Tejero et al. [24] on sweet orange and Stagno et al. [25] on mature orange trees.

4. CONCLUSION

Based upon the results, the following conclusions were drawn:

- The plant growth and yield parameters were observed maximum for meeting 100% of crop water requirement with the application of straw mulch and minimum for meeting 50% of crop water requirement without mulch.
- The observed soil moisture content was found higher in plastic mulched treatments, followed by straw mulched treatments and lower in no mulched treatments. So, plastic and straw mulch can be used where evaporation losses are more.
- The irrigation water use efficiency was found maximum for meeting 50% crop water requirement with the application of straw mulch and minimum for meeting 100% crop water requirement without mulch. So, drip irrigation at 50% crop water requirement in combination with straw mulch can be used as an effective tool for the improvement in irrigation water use

efficiency with reduction in the irrigation requirements of papaya crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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