Original Research Article

Effect of irrigation levels and straw mulching on yield and water use efficiency of Papaya under drip irrigation system.

ABSTRACT

Papaya (*Carica papaya* L.) is an important fruit crop in many tropical and subtropical regions of the world. However, its cultivation is often constrained by limited water availability and soil moisture stress, which may significantly affect its yield and quality. The present study investigated the effect of irrigation levels and straw mulch on growth and yield of papaya under drip irrigation system. The experiment comprised of six treatments *viz.,* three different irrigation levels (50%, 75% and 100% of crop water requirement) and two mulching levels (straw mulching and no mulch). The effect of mulching on plant growth and yield parameters was found statistically significant ($p<0.05$). The results revealed that the application of 100% of crop water requirement along with straw mulch resulted in the highest plant height, stem diameter and yield compared to the no mulch treatment. From the results, it is also observed that the irrigation water use efficiency (58.47 kg m^{-3}) was found maximum under 50 % of crop water requirement with straw mulch treatment and minimum for 100% of crop water requirement without mulch treatment under drip irrigation system.

Keywords: (Irrigation levels, Straw mulching, irrigation water use efficiency, Drip irrigation, Papaya)

1. INTRODUCTION

Papaya (*Carica papaya* L.) is an important tropical fruit crop that is widely grown in many countries, including India, Thailand, Brazil and Mexico. Papaya is a rich source of vitamins A, C and E, and has been shown to have many health benefits such as reducing the risk of cancer, cardiovascular disease and digestive disorders. The global demand for papaya has been increasing due to its nutritional and medicinal properties. However, papaya production is constrained by various biotic and abiotic factors, including water shortage stress.

Irrigation is a crucial factor in papaya production as it affects growth, yield and fruit quality. Insufficient irrigation can result in reduced growth, yield and fruit quality, while excessive irrigation can lead to water logging, root rot and reduced fruit quality. Therefore, the application of appropriate irrigation levels is essential to optimize papaya production. Drip irrigation, which has an irrigation efficiency of more than 90%, is one of the most modern and effective irrigation techniques. Comparing the drip irrigation technique to the conventional irrigation method, the crop production is often increased by 25–30% and irrigation water is also saved by 50–60% [1].

Mulching is another important cultural practice that can improve soil moisture conservation, reduce weed growth and improve soil fertility [2]. Mulching can also regulate soil temperature, thereby influencing plant growth and development. Straw mulching is a common agricultural practice used to improve soil quality and increase crop yield. It involves the application of a layer of straw on the soil surface to reduce water loss through evaporation, maintain soil moisture and suppress weed growth. Straw mulch acts as a barrier between the soil surface and the atmosphere, reducing water loss through evaporation. This reduces the need for frequent irrigation, leading to significant water savings. Additionally, straw mulching can improve soil structure, aeration, and nutrient availability, leading to healthier and more productive fruit trees. Several studies have reported positive effects of straw mulching on fruit crops [3] [4] [5].

Several studies have investigated the effect of different irrigation levels and mulching methods on various crops such as maize, tomato and cucumber [6] [7] [8]. However, limited research has been conducted on the effect of irrigation levels and mulching methods on papaya. Therefore, the present study aimed to investigate the effect of irrigation levels and straw mulching on the growth, yield and water use efficiency of papaya.

2. MATERIAL AND METHODS

The experiment was carried out at the research field of Deendayal Upadhyay Centre of Excellence for Organic Farming, CCS Haryana Agricultural University, Hisar ($29^0$08'09.3" N, $75^0$42'16.0" E and 215.2 m above sea level) during 2021-22. The soil at the experimental site was sandy loam with a pH of 6.5. The present investigation was laid out in split plot design and replicated thrice. The treatment comprised of three irrigation levels *viz.,* 100, 75 and 50% of crop water requirement in the main plot and two mulching levels *viz.,* straw mulch and no mulch in the sub plot. The different treatments combinations of irrigation levels and mulching levels are presented in Table 1.

Irrigation levels:
I100 - 100 % of crop water requirement
I75 - 75 % of crop crop water requirement
I50 - 50 % of crop crop water requirement
Mulching levels:
SM - 5 cm thick straw mulch in two-meter diameter around the plant
NM - No mulch

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

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

45 days old seedlings of papaya variety “Red Lady” were transplanted at spacing of 2 m X 2 m in the first week of March. The experimental field was irrigated as per treatment by using climatologically approach. The amount of water applied was estimated with the help of meteorological data recorded by Department of Agricultural Meteorology, COA, CCS Haryana Agricultural University, Hisar. The amount of irrigation water to be applied was calculated by following formula [9].

$$V=\frac{W_a \times PE \ \times P_C \times K_C}{EU} \qquad (1)$$

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 [10]

EU = Emission uniformity of the system (considered as 90%)

Soil samples were collected periodically (90, 120 and 150 days after transplanting (DAT)) to determine the soil moisture on dry basis. Soil samples were collected with the help of a tube auger at 0-30 cm depth below the soil surface and 30 cm away from dripper, perpendicular to lateral. Mass of soil samples was observed before and after drying the samples and moisture content (dry basis) was determined by equation 2.

$$\text{Moisture content } (\%) = \frac{M_1 - M_2}{M_2} \times 100 \qquad (2)$$

Where,

M_1 = mass of soil sample before drying (g)
M_2 = mass of soil sample after drying (g)

The relationship between yield and irrigation water is represented by irrigation water use efficiency (IWUE). IWUE was calculated by comparing the fruit yield per hectare to the amount of water used in each treatment.

$$\text{IWUE}\left(\text{kg m}^{-3}\right) = \frac{\text{Total curd yield}\left(\text{kg ha}^{-1}\right)}{\text{Amount of water applied}\left(\text{m}^3\text{ ha}^{-1}\right)} \qquad (3)$$

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 recorded during the crop period. OPSTAT software [11] was used to analyse the collected data for statistical significance using the split-split plot design.

3. RESULTS AND DISCUSSION

3.1 Soil Moisture Content

The soil moisture content of the soil was determined on dry basis using the gravimetric method at 90, 120 and 150 days after transplanting (DAT) is shown in Figure 1. Soil samples were collected from a depth of 0-30 cm below the soil surface, using a tube auger, 30 cm away from the plant. The soil moisture content was recorded maximum (16.44, 16.88 and 18.54 %) for I1$_{00}$SM and minimum (9.11, 10.18 and 10.58 %) for I_{50}NM at 90, 120 and 150 days after transplanting (DAT), respectively.

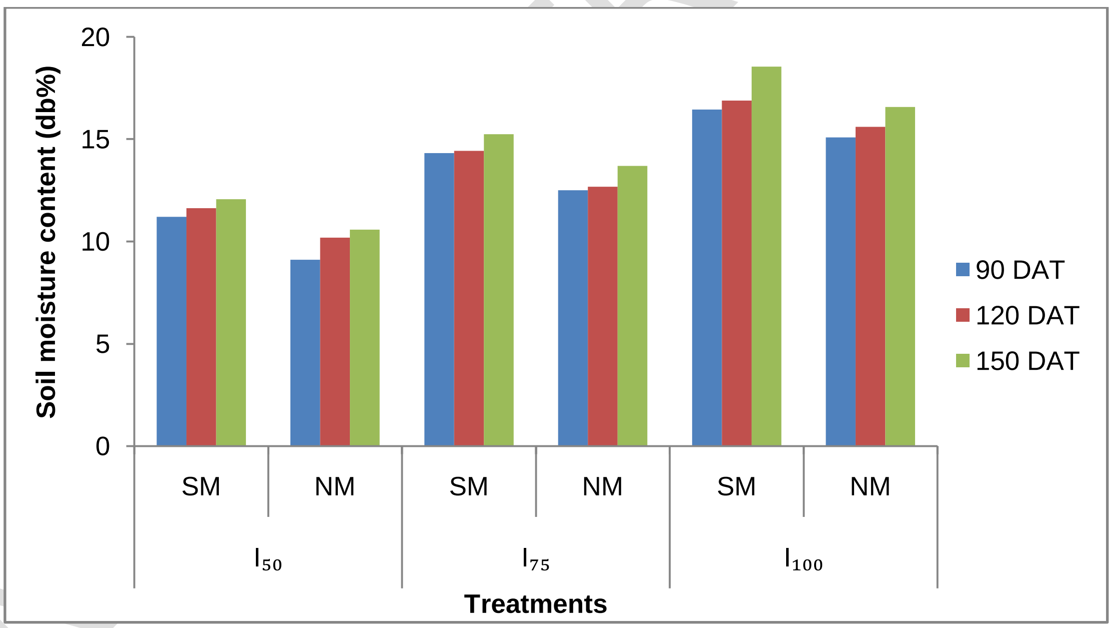

Fig. 1. Soil moisture for different treatments combinations at 90, 120 and 150 DAT.

3.2 Growth Parameters

3.2.1 Plant height (cm)

The interaction of irrigation levels and mulching levels on average plant height at harvesting is shown in Figure 2. Though the interaction of irrigation levels and mulching levels on average plant height was found statistically non-significant but average plant height was found maximum (237.67 cm) for treatment I_{100}SM and minimum (186.27 cm) for treatment I_{50}NM at harvesting. The effect of different irrigation levels on average plant height was found statistically significant and maximum average plant height was found for I_{100} (232.07 cm), followed by I_{75} (214.60 cm) and minimum average plant height was found for I_{50} (193.63 cm) at harvesting. The effect of mulching levels on average plant height was also found statistically significant and maximum average plant height was found for SM (219.67 cm) and minimum for NM (207.20 cm) at harvesting.

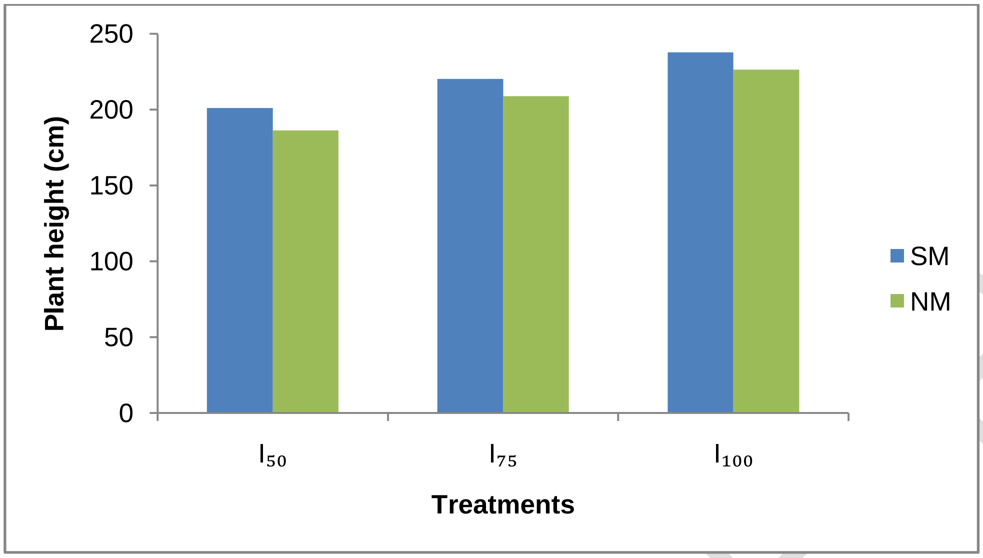

Fig. 1. Average plant height of papaya for different treatment combinations at harvesting.

3.2.2 Stem girth (cm)

The interaction of irrigation levels and mulching levels on average stem girth was found statistically non-significant but average stem girth was found maximum (45.63 cm) for treatment I_{100}SM and minimum (32.97 cm) for treatment I_{50}NM at harvesting. The interaction of irrigation levels and mulching levels on average stem girth at harvesting is shown in Figure 3. The effect of different irrigation levels on average stem girth was found statistically significant and maximum average stem girth was found for I_{100} (44.15 cm), followed by I_{75} (39.82 cm) and minimum average stem girth was found for I_{50} (34.85 cm) at harvesting. The effect of mulching levels on average stem girth was found statistically significant and maximum average stem girth was found for SM (41.22 cm) and minimum for NM (37.99 cm) at harvesting.

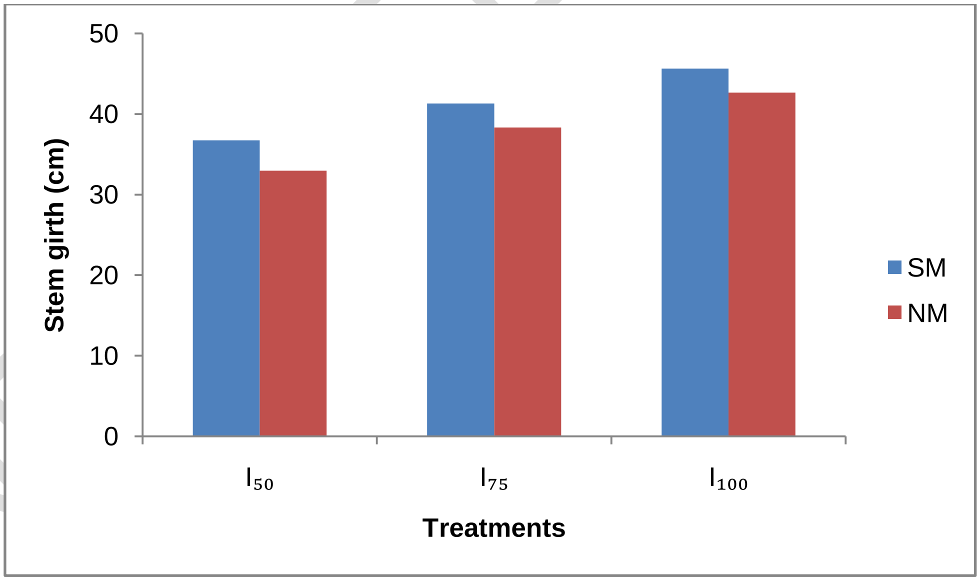

Fig. 3. Average stem girth of papaya for different treatment combinations at harvesting.

3.2.3 Crown diameter (cm)

The interaction of irrigation levels and mulching levels on average crown diameter was found statistically non-significant but average crown diameter was found maximum (242.33 cm) for treatment I_{100}SM and minimum (190.93 cm) for treatment I_{50}NM at harvesting. The interaction of irrigation levels and mulching levels on average crown diameter at harvesting is shown in Figure 4. The effect of different irrigation levels on average crown diameter was found statistically significant and maximum average crown diameter was found for I_{100} (236.73 cm), followed by I_{75} (219.27 cm) and minimum average crown diameter was found for I_{50} (198.3 cm) at harvesting. The effect of mulching levels on average crown diameter was found statistically significant and maximum average crown diameter was found for SM (224.33 cm) and minimum for NM (211.87 cm) at harvesting.

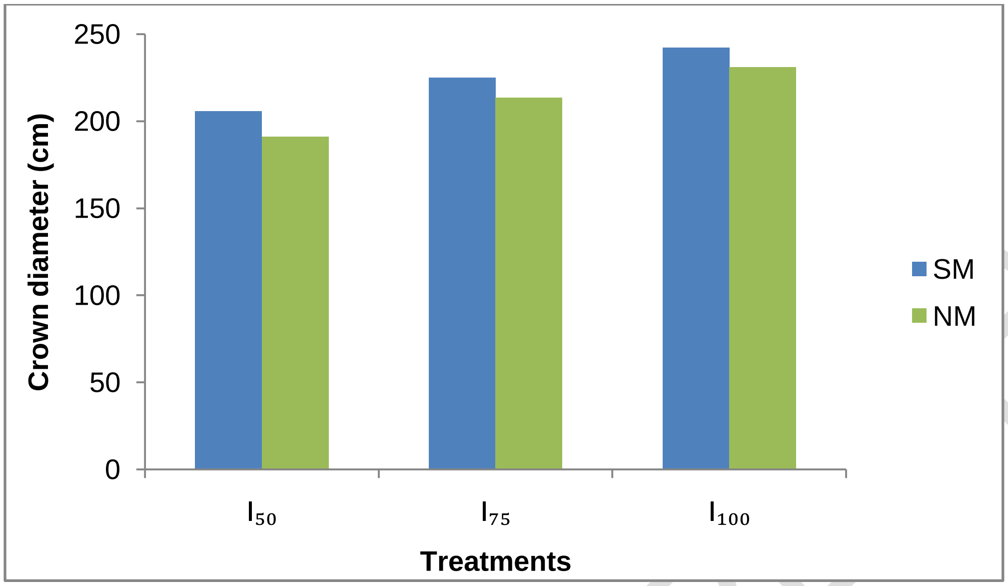

Fig. 4. Average crown diameter of papaya for different treatment combinations at harvesting.

3.3 Yield parameters

3.3.1 Number of fruits

The interaction of irrigation levels and mulching levels on average number of fruits was found statistically non-significant but average number of fruits was found maximum (42) for treatment I_{100}SM and minimum (32.33) for treatment I_{50}NM at the time of harvesting. The interaction of irrigation levels and mulching methods on average number of fruits at harvesting is shown in Figure 5. The effect of different 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 harvesting. The effect of mulching levels on average number of fruits was found statistically significant and the maximum average number of fruits was found for SM (38.11) and minimum for NM (36.11) at harvesting.

3.3.2 Yield per plant (kg)

The interaction of irrigation levels and mulching levels on average yield per plant was found statistically non-significant but average yield per plant was found maximum (53.60 kg) for treatment I_{100}SM and minimum (35.83 kg) for treatment I_{50}NM at harvesting. The interaction of irrigation levels and mulching levels on average yield per plant at harvesting is shown in Figure 6. The effect of different irrigation levels on average yield per plant was found statistically significant and maximum average yield per plant was found for I_{100} (51.78 kg), followed by I_{75} (44.78 kg) and minimum average yield per plant was found for I_{50} (36.27 kg) at harvesting. The effect of mulching levels on average yield per plant was also found statistically significant and the maximum average yield per plant was found for SM (46.20 kg) and minimum for NM (43.02 kg) at the harvesting.

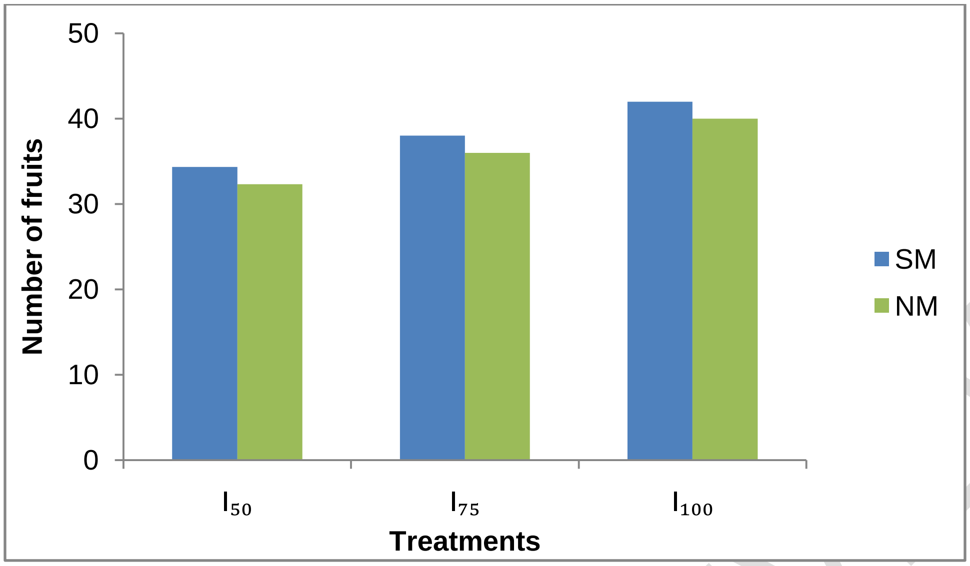

Fig. 5. Average number of fruits for different treatment combinations at harvesting.

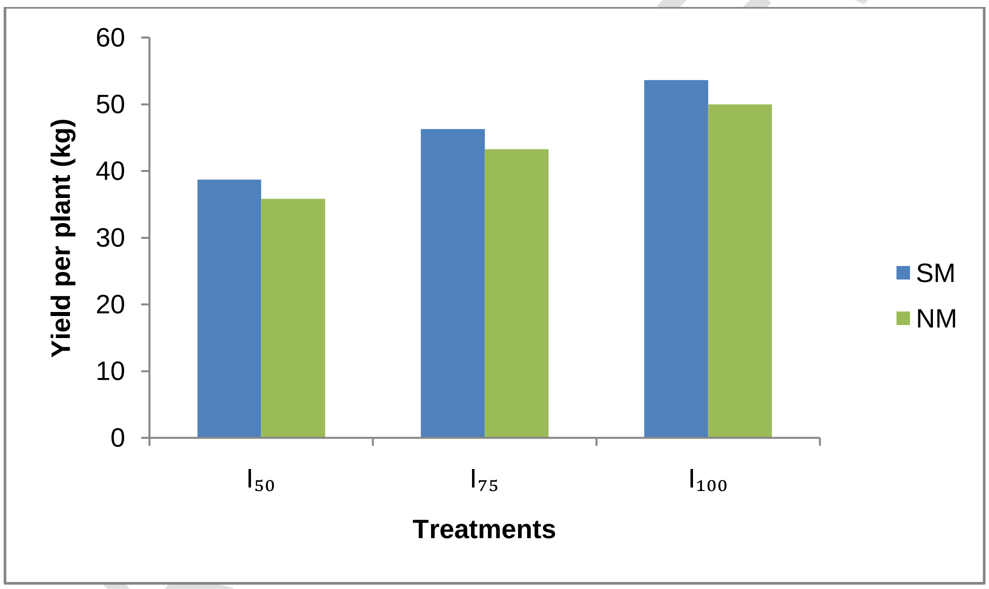

Fig. 6. Average yield per plant for different treatment combinations.

3.3.3 Yield (t ha^{-1})

The interaction of irrigation levels and mulching levels on average yield per hectare was found statistically non-significant but average yield per hectare was found maximum (133.96 t ha^{-1}) for treatment I_{100}SM and minimum (89.58 t ha^{-1}) for treatment I_{50}NM at the harvesting. The interaction of irrigation levels and mulching levels on average yield per hectare at harvesting is shown in Figure 7. 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} (129.44 t ha^{-1}), followed by I_{75} (111.96 t ha^{-1}) and minimum average yield per hectare was found for I_{50} (93.17 t ha^{-1}) at harvesting. The effect of mulching levels on average yield per hectare was found statistically significant and the maximum average yield per hectare was found for SM (115.49 t ha^{-1}) and minimum for NM (107.56 t ha^{-1}) at harvesting.

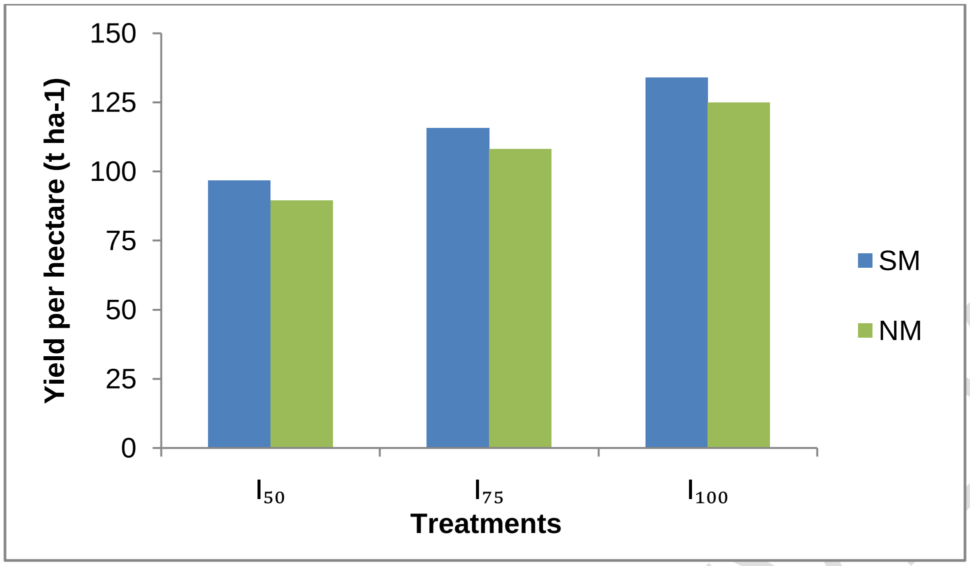

Fig. 7. Average yield per hectare for different treatment combinations.

- The effect of different irrigation levels on plant growth and yield parameters was found statistically significant and these parameters were found maximum for I_{100} and minimum for I_{50}. This might be due to the fact that higher levels of irrigation helps in maintaining the water stress free conditions for optimum growth and development of plants throughout the crop growing period. This outcome with previous studies reported by [12] [13] [14].
- The effect of mulching levels on plant growth and yield parameters was found statistically significant. The plant growth and yield parameters were found maximum for SM and minimum for NM. This might be due to fact that the use of mulch at the soil surface resulted in relatively less evaporation losses which maintains greater soil moisture availability in straw mulched treatments as compared to no mulched treatments. This observation is consistent with the findings of [14].

3.4 Irrigation water use efficiency

The interaction of irrigation levels and mulching levels on average irrigation water use efficiency was found statistically non-significant but average irrigation water use efficiency was found maximum (58.47 kg m^{-3}) for treatment I_{50}SM and minimum (42.64 kg m^{-3}) for treatment I_{100}NM. The interaction of irrigation levels and mulching levels on average irrigation water use efficiency at harvesting is shown in Figure 8.

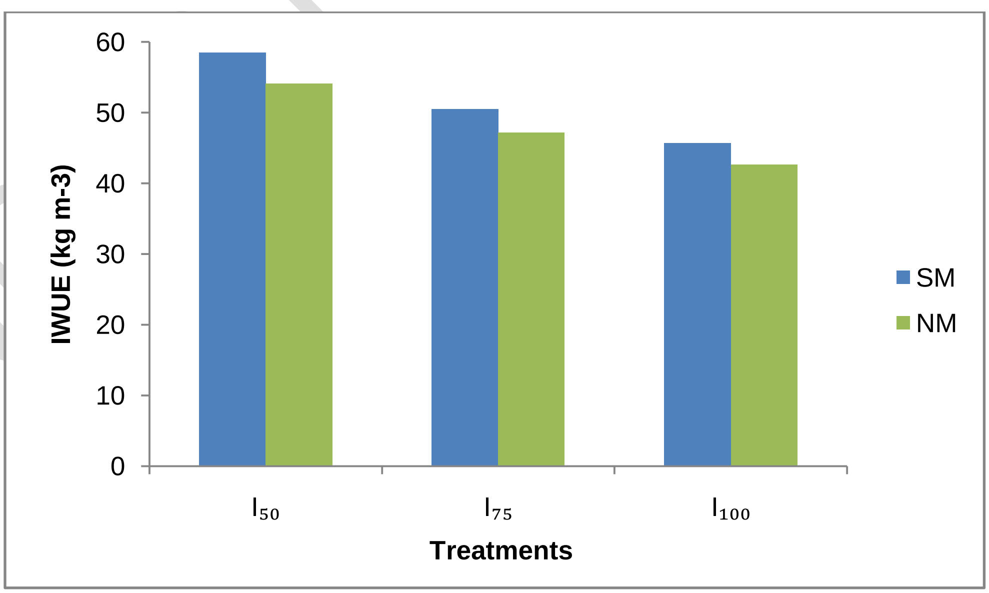

Fig. 8. Irrigation water use efficiency for different treatment combinations.

The effect of different irrigation levels on average irrigation water use efficiency was found statistically significant and maximum average irrigation water use efficiency was found for I_{50} (56.30 kg m^{-3}), followed by I_{75} (48.85 kg m^{-3}) and minimum average irrigation water use efficiency was found for I_{100} (44.19 kg m^{-3}) at harvesting.

The effect of mulching levels on average irrigation water use efficiency was found statistically significant. The maximum average irrigation water use efficiency was found for SM (51.57 kg m^{-3}) and minimum for NM (47.99 kg m^{-3}). The reason for this could be that the use of straw mulch during the early stages of growth resulted in a reduction in moisture loss through evaporation, leading to a decrease in water usage.

Conclusion

From the results it can be concluded that

- Regarding soil moisture content, the straw mulched treatments showed the highest levels while the no mulched treatments had the lowest soil moisture content. Therefore, straw mulch can be beneficial in areas with higher evaporation losses.
- The plant growth and yield parameters were found maximum when meeting 100% of the crop water requirement with straw mulch. Conversely, the minimum values were observed when meeting 50% of the crop water requirement without mulch.
- In terms of irrigation water use efficiency, it was found to be maximum when meeting 50% of the crop water requirement with straw mulch and minimum when meeting 100% of the crop water requirement without mulch. This suggests that combining drip irrigation at 50% crop water requirement with straw mulch can effectively improve irrigation water use efficiency and reduce the overall irrigation needs for papaya.

REFERENCES

[1] Fanish SA, Muthukrishnan P & Santhi P. Effect of drip fertigation on field crops-a review. Agricultural Reviews. 2011; 32(1).

[2] Singh R, Babu S, Avasthe RK, Yadav GS, Das A, Mohapatra KP, Kumar A, Singh VK & Chandra P. Crop productivity, soil health, and energy dynamics of Indian Himalayan intensified organic maize-based systems. International Soil and Water Conservation Research. 2021; 9(2): 260-270.

[3] Chakraborty D, Nagarajan S, Aggarwal P, Gupta VK, Tomar RK, Garg RN, Sahoo RN, Chopra KS, Sharma KSS & Kalra N. Effect of mulching on soil and plant water status and the growth and yield of wheat (*Triticum aestivum* L.) in a semiarid environment. Agricultural Water Management. 2018; 95(12): 1323-1334.

[4] Lamont WJ. Plastics: Modifying the microclimate for the production of vegetable crops. Horticulture Technology. 2005; 15: 477-481.

[5] Memon MS, Zhou J, Guo J, Ullah F, Hassan M, Ara S & Ji C. Comprehensive review for the effects of ridge furrow plastic mulching on crop yield and water use efficiency under different crops. International Agricultural Engineering Journal. 2017; 26(2): 58-67.

[6] López-Gómez M, Ortiz-Bernal LE, Quiroz-Cardoso E, Rangel-Peraza JG & Peña-Bautista RJ. Effect of irrigation frequency and mulching on yield and water use efficiency of tomato (*Solanum lycopersicum* L.). Journal of Applied Botany and Food Quality. 2016; 89: 237-242.

[7] Huang Y, Huang R, Sun J, Hu H and Huang Z. Effects of different irrigation levels and mulching methods on yield, water use efficiency and fruit quality of cucumber under drip irrigation. Agricultural Water Management. 2019; 217: 47-54.

[8] Mosa AA, El-Sayed ME and El-Tohamy WA. Response of maize crop to different irrigation regimes and mulching treatments under sandy soil conditions. Archives of Agronomy and Soil Science. 2021; 67(8): 1065-1076.

[9] Doorenbos J & Pruitt WO. Crop Water Requirements. FAO Irrigation & Drainage Paper. 1977; 24.

[10] López T, Martínez R, Puig O, Paredes P, Pereira LS, Chaterlan Y & Hernández G. Estimation of the Papaya crop coefficients for improving irrigation water management in South of Havana. In VI International Symposium on Banana: XXVIII International Horticultural Congress on Science and Horticulture for People. 2010; 179-186.

[11] Sheoran OP, Tonk DS, Kaushik LS, Hasija RC and Pannu RS. Statistical Software Package for Agricultural Research Workers. Recent Advances in information theory, Statistics & Computer Applications, Department of Mathematics & Statistics, CCS HAU, Hisar. 1998; 139-143.

[12] Datta S and Chatterjee R. Effect of Irrigation regimes on moisture extraction pattern evapotranspiration and yield of 93 fenugreek (*Trigonella foenum-graecum*). Journal of Spices and Aromatic Crops. 2006; 15(2): 125-129.

[13] Devi B, Bhunia S, Sunita & Sarita. Effect of irrigation levels on yield, water use, water use efficiency and NPK uptake of fennel (*Foeniculum vulgare Mill.*) cultivars grown under drip system. The Pharma Innovation. 2022; 11(4): 1994-1996.
[14] Gaat , B. S., Kumar , M., Naresh , R., Kumar , S., Kapil, Kumar , R., Vijay, & Anshul. Effect of Different Irrigation Levels and Mulching Methods on Performance of Organically Cultivated and Drip Irrigated Papaya. International Journal of Plant & Soil Science. 2023; 35(16): 46–55.