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Comparative Study of Drip and Ring Basin Irrigation Methods for Young Mango and Jujube Orchard at Farmers' Field in Tando Allahyar

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ABSTRACT

Pakistan ranks 5th globally in mango production and 3rd in exports. Jujube, known locally as Ber, is vital in arid regions, resilient to drought. Boosting production and improving fruit quality require attention to factors like soil, plant variety, and weather. Water scarcity underscores the need for modern irrigation methods to enhance mango and jujube yields. A field experiment was conducted at Doctor Nasir Agriculture Farm, located at 25° N latitude and 68° E longitude, approximately 26 m above sea level. The experimental area covered 0.296 ha (54.86m x 53.92m). In this study, two treatments were used i.e. T1 (drip irrigated plants) and T2 (ring basin irrigated plants) at 50% soil moisture depletion level with three replications. The result of this experiment shows that the drip irrigation significantly influenced mango and jujube plant height, with no notable difference in stem girth and number of branches. The system demonstrated satisfactory performance, achieving 88.0% distribution uniformity for both lateral and the entire system. Notably, the study revealed a substantial 77% water savings with drip irrigation compared to ring basin, offering potential for revitalizing fallow land. Urgent awareness efforts are recommended within water-stressed farming communities to promote the adoption of drip irrigation for mango and jujube orchards.

KEYWORDS: Drip Irrigation, Jujube, Mango, Ring Basin Irrigation Method

1. INTRODUCTION

Water scarcity is a global issue and with the world's population projected to reach 9-10 billion, the demand for water will increase [1] The water scarcity for agriculture in arid and semi-arid regions increases the need for technologies to improve water use efficiency and production with reliable water access [2]. Drip irrigation is highly effective water saving irrigation technique. It can raise the productivity of water, fertilizer, improve crop, orchards output and quality [3]. Drip irrigation systems, adopted globally by farmers, save about 70-80% of irrigation water as compared to traditional methods [4].

Pakistan is an agricultural nation that is currently struggling with a water scarcity to meet the needs of various crops and orchards [5], [6]. Ensuring food security for present and future generations relies on sustainably using water resources and enhancing agricultural productivity through technologies that optimize water usage [7]. Pakistan, a key global fruit producer, holds the 4th position in mango production (1.88 million tons) and ranks 6th globally in jujube production. In 2021-22, fruit cultivation covered 746,628 hectares, yielding 6,963,577 tons [8]. Fruit exports earned around 50.699 billion Rupees domestically. Notably, Sindh Province played a vital role, cultivating 59,150 hectares of mangoes with a production of 387,884 tons, as per [9]

Mango, known as the King of fruits, boasts numerous varieties each year. Likewise, jujube, locally called Ber (Ziziphusmauritiana L.), is a crucial and resilient fruit tree in arid and semi-arid regions. China dominates jujube production, contributing 98% to the world's total, reaching 8.78 million tons in 2018 [10] In Pakistan, jujube has been successfully cultivated in Hyderabad, Khairpur, Multan, Sargodha, and Lahore districts. There are many grafted varieties of jujube that are under cultivation in different irrigated areas of Sindh which includes Soofi, Kheerol (Chambeli), Sanghari, Gola and Dehli Gola. The Gola seems to be the variety included in this study is most popular variety which has two types, the Green leemai and the Golden white (Khushk et al., 2013). Jujube fruit is one of the nutritious fruits of the world [11] and is also named as “Poor’s Apple”.

Tando Allahyar, district in Sindh, Pakistan, face water scarcity challenges despite cultivating various crops like cotton, wheat, sugarcane, fruits, and vegetables. The installation of drip irrigation systems in these districts can alleviate water scarcity issues and potentially address waterlogging concerns in crops, vegetables, and orchards. The economic significance of mango and jujube fruits, it is imperative to boost production and enhance fruit quality. Mango and jujube orchards represent long-term investments, providing extended fruit-bearing periods. Well-suited to tropical and sub-tropical climates, these fruits, along with factors like soil, variety, and environment, are particularly dependent on water. Given the country's limited water resources, adopting micro-irrigation methods becomes essential for maximizing mango and jujube production.

While distribution uniformity studies of some types of drip or trickle irrigation systems have been undertaken, evaluation of the performance of drip irrigation systems such as that of dippers discharge and volume of wetting pattern at exiting hydraulic head for mango an jujube plant have not been fully explored. In fact, no rigorous study has been carried out to determine recommendable exiting operating head to generate certain levels of water distribution uniformity. This study was conducted to determine the effect of drip and ring basin irrigation method on growth of two different orchards plant.

2. MATERIALS AND METHOD

2.1. Design and description of the experimental area

A field experiment was conducted at Doctor Nasir Farm in District Tando Allahyar, with an elevation of 26 m above sea level (Figure 1). Tando Allahyar, a district in Sindh, Pakistan, facing water scarcity issues, common to many districts in the region (Figure 2). Despite challenges, the area engages in diverse crop cultivation such as cotton, wheat, sugarcane, fruits, and vegetables. To address water scarcity, implementing drip irrigation systems in crops, vegetable production, and orchards could be a viable solution.

The experimental site included a water tank, pumping unit, chemical mixing chamber, flow release pipe, water cleaning system, and pipes supplying water to mango and jujube trees. A drip irrigation system with two emitters per tree connected via micro tubes from lateral lines was used. These lines, linked to a sub-main line, were connected to the main water supply. Each mango and jujube tree received irrigation from two lateral lines, each with two emitters. The total experimental area was 0.296 ha. The study had two treatments (T1: drip irrigation, T2: ring basin irrigation) at a 50% soil moisture depletion level, with three replications. The research plot was equally divided for drip and ring basin irrigation, focusing on the "Sindhri" mango and Gola jujube varieties known for local adaptability and commercial value. Plant growth observations occurred from July to December, 2021, with a plant-to-plant distance of 4.57 m.

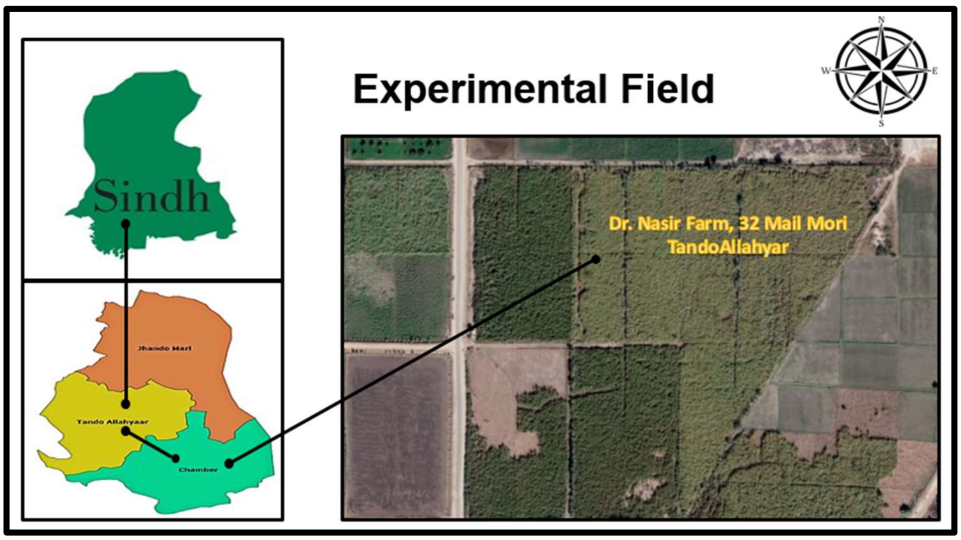

Figure 1: Bird eye view of the experiment site

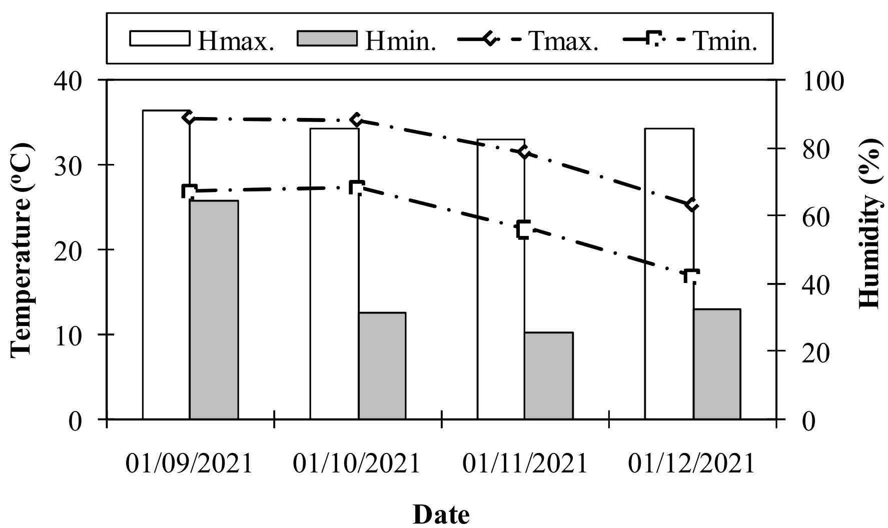

Figure 2: Mean minimum and maximum temperature and relative humidity during experimental period.

2.2. Determination of Soil Physical Properties

To assess the performance of drip and ring basin irrigation systems, crucial soil properties such as textural class, dry bulk density, field capacity, soil porosity, and infiltration rate were analysed. Soil samples were collected at varying depths (0-20, 20-40, 40-60, 60-80, 80-100 cm) from three locations in the experimental area for physical properties and up to 45cm for chemical properties. Composite soil samples from the field were analysed at the Department of Irrigation and Drainage, Faculty of Agricultural Engineering, Sindh Agriculture University, Tando Jam. Table 1 presents the average values of these parameters.

Table 1: Soil Analysis before Experiment up to 100cm

Soil Characteristics		**Values**
Physical Properties		
Sand (%)		24.16
Clay (%)		58.52
Silt (%)		17.32
Texture		Clay
Bulk Density (g/cm^3)		1.38g/cm^3
Soil porosity (%)		47.9
Filed Capacity (%)		38
Chemical Properties		
Soil pH	Depth at 0-15 cm	8.30
	Depth at 15-30 cm	8.17
	Depth at 30-45 cm	8.04
Soil EC_w (dS/m)	Depth at 0-15 cm	0.48
	Depth at 15-30 cm	0.62
	Depth at 30-45 cm	0.50

2.3. Fruit Varieties

The study focused on the popular Sindhri and Gola varieties of mango and jujube. While mango can grow from seeds, obtaining desired varieties is rare and expensive. Farmers typically use grafting techniques to ensure specific characteristics. Sindhri and Gola varieties were acquired from local farmers, transplanted into the field at an average age of one year.

2.4. Irrigation Delivery Scheme

Plants absorb soil moisture through their roots, emphasizing the need for adequate moisture in the root zone. Irrigation scheduling, guided by a 50% deficit in soil moisture content [12], ensures timely irrigation applications. The irrigation depth was calculated using following equation [13].

$$D = \frac{\text{SMD}}{100} \text{ x } \rho_{\text{d}} \text{ x } \text{d}_{\text{r}}$$

Following formulas were used to determine soil moisture deficit level;

$$SMD = \theta_f - \theta_o$$

$$\theta = \frac{(W_w - W_d)}{W_d} \times 100$$

Where, D = Depth of water required (cm), SMD = Soil moisture deficit level, ρ_d = Bulk density (grams cm^{-3}), d_r = Root depth (cm), θ_f = Moisture content at field capacity (%), θ_o = Moisture content at 50 % SMD, θ = Moisture content on dry weight basis (%), W_w = Wet weight of soil (g), and W_d = Oven dry weight of soil (g)

Each time, water has been applied to bring soil at field capacity. Soil samples for determining the moisture content were taken from basin around plant under both irrigation methods at various soil depths before the application of water. Moisture content was determined by oven drying the soil sample for 24 hrs at a temperature of 105 ^{0}C.

2.5. Irrigation Water Measurements for Drip Irrigated Plants

To apply the necessary water depth in the drip irrigation plot, the flow meter at the main pipeline's start was employed. The flow rate under the drip system was determined by recording the volume passing through the water meter. The difference in meter readings indicated the total water volume applied over a specific period Additionally, the discharge of each dripper/emitter was periodically measured using the volumetric method.

2.6. Irrigation Water Measurements for Basin Irrigated Plants

To apply the required depth of water to basin irrigation experimental plot a cut-throat flume of 8” x 1.5’ (20.32cm x 45.72cm) was installed at the head of the ridge for the measurement of irrigation water. The time of irrigation application to supply the required depth of water was calculated by equation and equation given by [16].

2.7. Application Uniformity

To assess water application uniformity in drip irrigation, containers were positioned beneath emitter/dropper points to collect flowing water. The start time of drip flow was noted, and after a specific interval, the flow was halted, and containers were removed. Volume collected in each container was measured with a graduated cylinder, and the recorded volume divided by the collection time yielded the discharge for each emitter/dropper. This discharge data was utilized to calculate uniformity coefficients and distribution uniformity.

2.8. Water Saving (%)

Water saving was determined by dividing difference in water used by drip over basin irrigation methods and procedure adopted by [14]which is an under.

$$W.S = \frac{W_a - W_b}{W_a} \times 100$$

Where: W.S = Water Saving (%), W_a = Total water used in basin irrigation method (m^3/ha), W_b = Total water used in bubbler irrigation method (m^3/ha).

2.9. Measurement of Mango and Jujube Plant Growth Parameters

Measurements of key plant growth parameters for young mango and jujube plants, including plant height (cm), stem girth (cm), and the number of branches per plant, were recorded each month [15]defined girth as the stem's circumference, measured with a Vernier calliper at 10 cm above the soil surface. Plant height was measured using a measuring tape from the ground level to the tip of the plant disk in centimetres. The plants were selected and tagged during these visits.

3. RESULTS AND DISCUSSION

This study was carried out to evaluate the performances of drip and ring basin irrigation methods on young mango and jujube plants growth. In order to achieve the objectives, it is imperative to determine the effects of the both irrigation systems on crop growth parameters and water saving. The information of these parameters adds significant value to explore the possibilities of transforming from the traditional ring basin irrigation method to drip irrigation method for the mango and jujube orchard.

3.1. Irrigation water quality and used

The data on quality of water applied during the irrigations are shown in Table 2. The quality of water has been based on EC and pH values determined. The values of EC and pH ranged between 0.22 to 0.29 dS/m and 8.2 to 8.7, respectively. The analysis of data reveal that the water can be termed as good quality water and can be applied directly without any danger provided that all other soil and management practices are observed properly. Since, the canal water is taken from River Indus, which is usually as 1st class water and hence, it is suitable for irrigation purpose. In this research, the irrigation scheduling was set that when the 50% of available moisture was depleted then the subsequent irrigations be applied as suggested by MINFAL [12]. Total volume of water per year applied to the plant under drip irrigation experimental plot was 37.75 m^3 $plot^{-1}$; that is the 52.43 m^3 ha^{-1}. Similarly, total volume of water applied to the crop under ring basin irrigation experimental plot was 168.63 m^3 $plot^{-1}$; that is 234.20 m^3 ha^{-1} (Figure 3).

Table 3 shows that the co-efficient of variation of laterals were 8.9, 11.5 and 10.1, respectively. Likewise the distribution uniformity of lateral 1, 2 and 3 were 90.7, 88.9 and 88.0 %, respectively. While the entire system distribution uniformity 88.0 %. These results suggested that the system was good to excellent i.e. satisfactory according to design as range are compared.

Table 2: Irrigation water application and its quality during experimental periods

Sr. No	Irrigation method				Water quality		
	Drip		Ring basin		Source	pH	ECw
	Date	Volume (m^3)	Date	Volume (m^3)			
1	2-Sep-21	1.51	2-Sep-21	15.33	SW	8.2	0.26
2	6-Sep-21	1.51	12-Sep-21	15.33	SW	8.17	0.21
3	10-Sep-21	1.51	21-Sep-21	15.33	SW	8.15	0.27
4	14-Sep-21	1.51	30-Sep-21	15.33	SW	8.19	0.25
5	18-Sep-21	1.51	9-Oct-21	15.33	SW	8.2	0.26
6	22-Sep-21	1.51	18-Oct-21	15.33	SW	8.24	0.22
7	26-Sep-21	1.51	27-Oct-21	15.33	SW	8.16	0.21
8	30-Sep-21	1.51	5-Nov-21	15.33	SW	8.19	0.26
9	4-Oct-21	1.51	14-Nov-21	15.33	SW	8.25	0.28
10	8-Oct-21	1.51	23-Nov-21	15.33	SW	8.22	0.25
11	12-Oct-21	1.51	1-Dec-21	15.33	SW	8.2	0.23
12	16-Oct-21	1.51			SW	8.24	0.27
13	20-Oct-21	1.51			SW	8.15	0.25
14	24-Oct-21	1.51			SW	8.21	0.22
15	28-Oct-21	1.51			SW	8.25	0.26
16	1-Nov-21	1.51			SW	8.18	0.28
17	5-Nov-21	1.51			SW	8.23	0.21
18	9-Nov-21	1.51			SW	8.19	0.24
19	13-Nov-21	1.51			SW	8.25	0.27
20	17-Nov-21	1.51			SW	8.22	0.22
21	21-Nov-21	1.51			SW	8.17	0.26
22	25-Nov-21	1.51			SW	8.24	0.28
23	29-Nov-21	1.51			SW	8.16	0.22
24	2-Dec-21	1.51			SW	8.25	0.26
25	5-Dec-21	1.51			SW	8.18	0.25
Volume m^3		**37.75**		**168.63**			

Table 3. Minimum discharge, average discharge, standard deviation, coefficient of variation, uniformity coefficient and distribution uniformity of existing system

Sr. No	Min. discharge q_m (gpm)	Av. discharge q_{avg}	$\Sigma(q - q_{av})^2$	σ	C_v	C_u	D_u
Lateral 1	0.0419	0.0474	0.00009	0.0042	8.9	92.8	90.7
Lateral 2	0.0407	0.0458	0.00014	0.0053	11.5	90.8	88.9
Lateral 3	0.0407	0.0476	0.00011	0.0048	10.1	91.9	88.0
System	0.0407	0.0469	0.00035	0.0049	10.3	91.7	88.0

Note: Min. is minimum, σ is standard deviation, C_v is coefficient of variation, C_u is uniformity coefficient, D_u is distribution uniformity

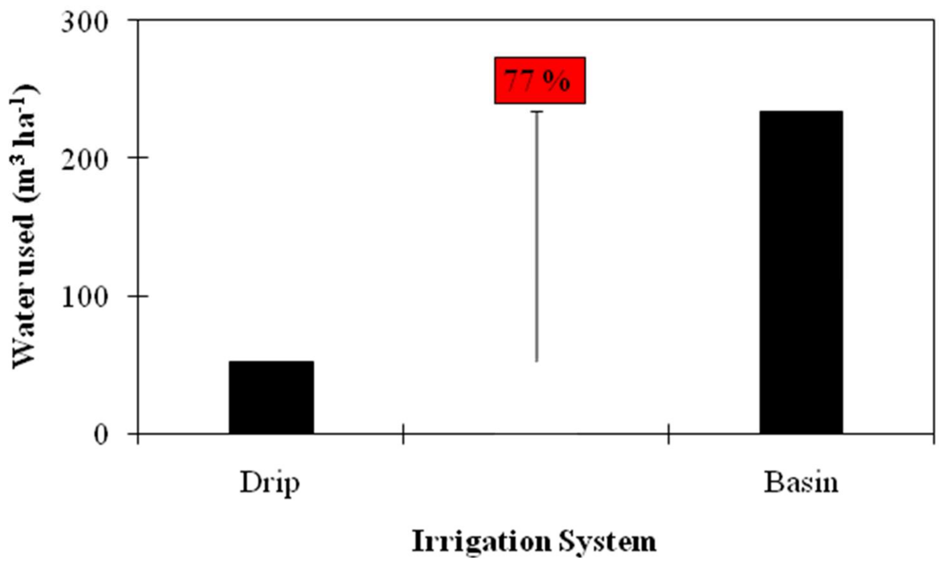

Figure 3: Total water used and water saving in the drip over ring basin irrigation method during experimental periods.

3.2. Plant Growth Parameters

The plant growth parameters, such as plant height, numbers of branches per plant and stem girth under drip and ring basin irrigation methods for were measured on monthly basis for the mango and jujube plants. Their average values are presented in Figures 4 to 6. The results revealed that the plant height, stem girth and number of branches per plant for the mango and jujube plants were increasing under both irrigation systems for four months duration. Drip irrigation, mango plants exhibited an average increase of 86 cm in height, 1.00 cm in stem girth, and 1.28 branches, while jujube plants showed increases of 224 cm, 3.92 cm, and 1.72 branches, respectively. In contrast, under ring basin irrigation, mango plants had average increases of 41 cm, 2.0 cm, and 0.89 branches, while jujube plants showed increases of 130cm, 5.11cm, and 1.83 branches. The results suggest a superior plant growth response under drip irrigation compared to ring basin irrigation.

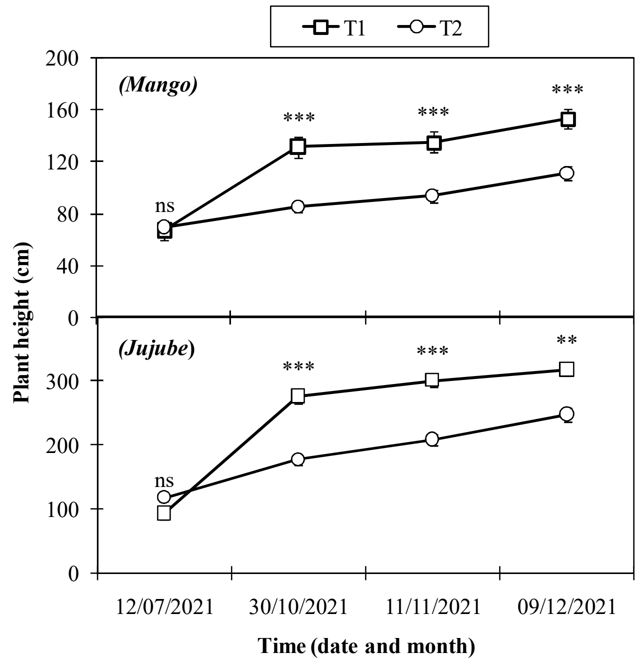

Figure 4: Effect of irrigation methods on plant height of mango and jujube plants during 2021 cropping season. Vertical bars are standard deviations of the means.

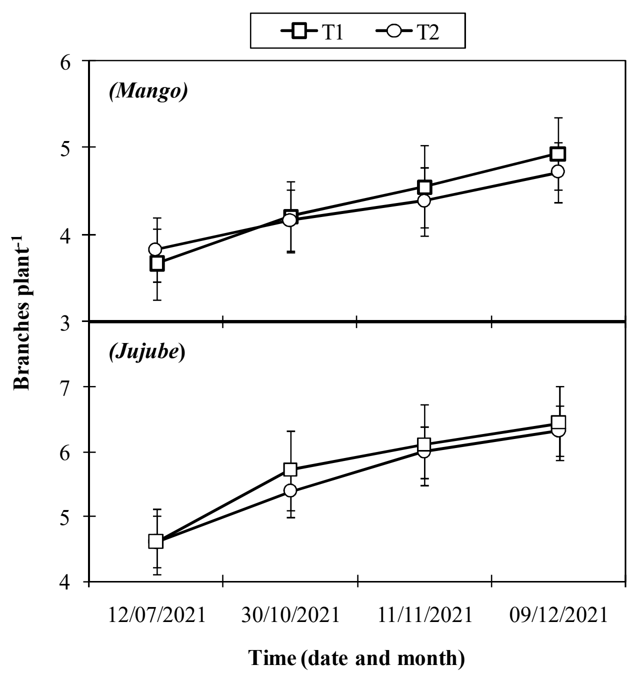

Figure 5: Effect of irrigation methods on branches per plant of mango and jujube plants during 2021 cropping season. Vertical bars are standard deviations of the means.

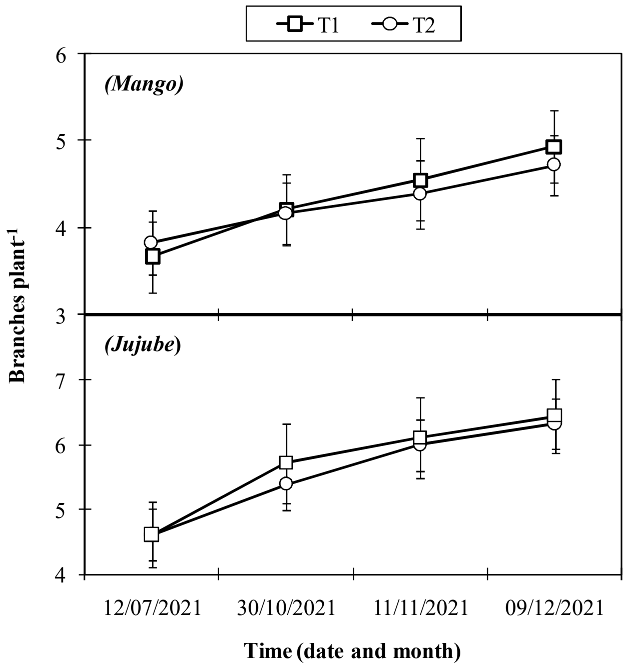

Figure 6: Effect of irrigation methods on stem diameter of mango and jujube plants during 2021 cropping season. Vertical bars are standard deviations of the means.

3.3. Water Saving

Drip irrigation yielded a water saving of 77.61%, which can be allocated to additional irrigated areas. This aligns with comparable studies on water consumption in traditional versus drip irrigation across different crops [13-15]. Figure 3, depicts the annual water consumption under both methods, highlighting the significant water savings achieved with drip irrigation. It's important to note that total water requirements for crops can vary based on factors such as climate, location, growing period, and chosen irrigation criteria, as emphasized in previous research.

4. CONCLUSION

The distribution uniformity values of drip irrigation system were 88%, which indicates that the drip irrigation system was working satisfactory according to its design. Plant height of mango and jujube were significantly affected due to irrigation methods, and numbers of branches per plant and stem girth were not significantly affected among the treatments. The 77% of water can be saved under drip irrigation as compared to ring basin irrigation method that could be utilized to irrigate the additional fallow agricultural land. The drip irrigation method controls the weed growth that can save the labour. The present study needs to be continued to observe the long-term effects on plant growth under the drip and ring basin irrigation methods and device the concrete recommendation.

Conflicts of Interest: There are no conflicts of interest reported by the writers.

Authors contributions: RR is the first author and did all work related to methodology under the supervision of Dr. Rajesh Kumar Soother, and Muhammad Uris Mirjat, which helped in research work.

Data Availability statement

The data presented in this study are available on request from the corresponding author.

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