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MINIMIZATION OF FROST INJURY IN MANGO CV. SINDHRI VIA DIFFERENT IRRIGATION LEVELS

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ABSTRACT

Mango is one of the most important fruit crops all over the world. It is the second-most significant fruit crop in Pakistan. The standardization of irrigation needs for the mango crop is one of the primary and most crucial factors for reducing frost injury, improving fruit quality, and yield, which must be taken into account. Low moisture content in the soil increases the likelihood of frost injury, so it is essential to maintain an ideal amount of moisture to mitigate such damage. To conserve valuable irrigation water, apply water only during critical stages. Research was conducted at the Experimental Orchard of Makhdom Ahmad Aalam Anwar, Mohsin Abad, during 2020-21 and 2021-22. Mango trees of the Sindhri variety were of uniform age (20 years) for this experiment. The experimental layout was a randomized complete block design. Irrigation was applied to mango trees at three different moisture levels (35-40%, 30-35%, and 25-30%) that were measured and maintained via the HH_2 Moisture Meter (Version 2.3). The mango trees showed good results at the 35-40% soil moisture level compared with the rest of the treatments, especially in terms of vegetative growth. Fruit size, yield per tree, and total soluble solids of the fruit were maximum in mango trees irrigated at 35-40%. Minimum frost incidence (21%) was observed at the 35-40% moisture level, while maximal damage by frost (37%) was noticed in plants subjected to the 25-30% moisture level. This study concludes that moisture level is more important for enhancing mango yield. It will be more supportive for future work on the impact of frost injury in the mango crop.

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INTRODUCTION

Mango (*Mangifera indica* L.) is the second most producing fruit crop of Pakistan being cultivated on an area of 171.3 thousand hectares with more than 1.7 million tons of annual production. Pakistan is sixth largest mango producing country after China, India, Kenya, Thailand, and Indonesia (Romero et al., 2004a, b, Nasir et al., 2014; Kausar et al., 2021; Shahbaz et al., 2023). Pakistan's mango production has not been up to the mark despite of having the great potential for mango production and exports, especially from the southern areas of Punjab (Romero et al., 2004c).

The mango plant possesses a deep and extensive root system, along with expanded leaves featuring a thick cuticle. These adaptive characteristics enable the mango plant to withstand periods of drought (FAO, 2022; Zahid et al., 2022). Mango exhibits a unique adaptive mechanism, categorizing it as a drought-resistant crop. However, consistent and appropriate irrigation is necessary throughout the year for commercial fruit production.

Mango has varying water requirements during different phenological phases. Other factors, such as orchard age and climatic conditions, also influence mango's water needs. In tropical regions, limited irrigation is required to initiate the flowering process of mango. After the onset of fruiting, water tension must be significantly reduced within the first four to six weeks after anthesis (Bally, 2006). The fruit growth and development phase is critical in the mango reproductive cycle, making irrigation management essential. Water deficiency during this phase significantly impacts production.

Various deficit irrigation schemes can be employed, with the primary distinction lying in how the irrigation rate is distributed throughout the season. Sustained Deficit Irrigation (SDI) involves consistent water limitation based on the crop's water needs, particularly during less vulnerable phenological periods of the production cycle. The Sensor-based irrigation strategy, when compared to the control using the standard FAO-56 approach, resulted in 26% water saving with no significant changes in production observed. However, crop water efficiency improved by 33% in the mandarin orchard (Martinez-Gimeno et al., 2020). This technique allows the crop to adapt to stressful conditions (Carr, 2014). The irrigation needs of mango have not been thoroughly examined, with limited research focusing on developing irrigation methods for the entire fruiting season rather than comparing alternative water management systems at distinct phenological stages.

Water scarcity in agricultural fields is a global issue nowadays. The quantity of water for agricultural use is declining worldwide (Jury and Jr, 2005; Tzanakakis et al., 2020). Additionally, undistributed precipitation patterns are increasing globally due to climate change (Cui et al., 2009). These conditions may lead to socio-economic issues such as reduced yields and increased costs of irrigation water. Therefore, the adoption of water conservation methods is crucial, especially for fruit trees with high water requirements. Farmers cannot afford to miss a season when a water deficit is anticipated. This situation has prompted the invention and adoption of various water-saving irrigation methods and technologies, such as surface irrigation or managed deficit irrigation, to conserve water and improve the water-use efficiency (WUE) of crops (Romero et al., 2004c; Somasundaram et al., 2020). Consequently, the present research was designed to determine the ideal degree of soil moisture around the roots to achieve the maximum quality yield of mango under the scenario of climate change.

MATERIALS AND METHODS

The present research was conducted at the Experimental Orchard of Makhdom Ahmad Aalam Anwar, Mohsin Abad, during the seasons of 2020-21 and 2021-22. Mango trees of the Sindhri variety, all of uniform age (20 years), were selected for this experiment. Four treatments, including a control, were implemented, with each treatment repeated five times. The mango trees were irrigated using a channel basin system. Soil moisture was measured using an HH_2 Moisture Meter (Version 2.3) with the Profile Probe PR_2 for mineral soil (clay loam), as depicted in Figure 1.

Irrigation was applied to mango trees at three different moisture levels: 35-40%, 30-35%, and 25-30% in the upper 100-600 cm of the root zone, with each moisture level considered as a single treatment (Table 1).

Vegetative growth stage after harvest

The number of flushes produced by the plants per year was calculated. Four branches were tagged in each direction, and data were collected from them for two consecutive years, with the average calculated. Leaf length and leaf width of mature and fully expanded leaves were measured using measuring tapes and expressed in centimeters. The number of irrigations made to maintain the requisite level of soil moisture under this phenological stage was also recorded.

Frost injury

The damage to foliage caused by frost injury (%) was computed on tagged branches using the following formula:

$$\text{Damage caused by frost} = \frac{\text{Damaged branches}}{\text{Total no.of tagged branches}} \times 100$$

Flowering and fruit setting stage

This is the second phenological stage of the mango tree. During this stage, the number of irrigations made to maintain the requisite level of soil moisture was

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calculated. The length of the flowering panicle (cm) was measured using a measuring tape.

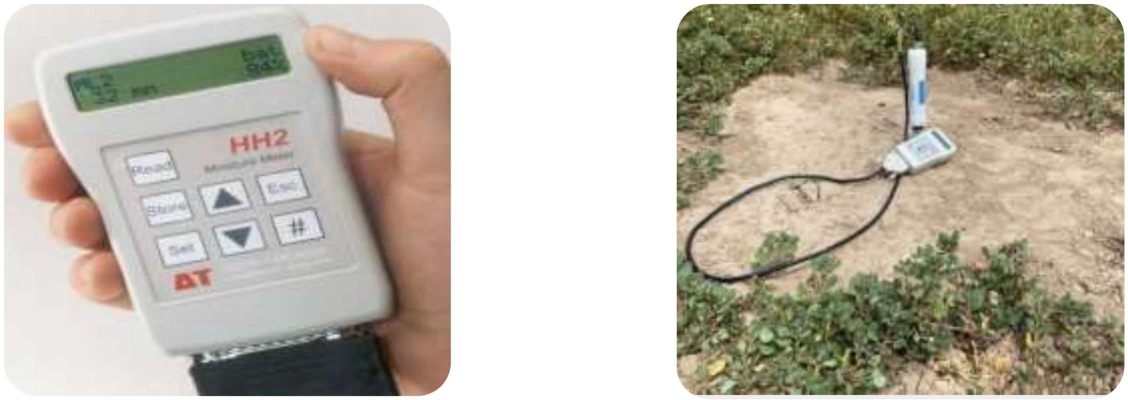

Figure 1. The HH_2 Moisture Meter (Version 2.3).

Table 1: Irrigation under different moisture levels.

Treatment	Treatment detail
T1	Irrigation at 35-40 % soil moisture in upper 100-600 cm of root zone.
T2	Irrigation at 30-35 % soil moisture in upper 100-600 cm of root zone.
T3	Irrigation at 25-30 % soil moisture in upper 100-600 cm of root zone.
T4	Conventional method, maintenance

Fruit development up to harvest

This is the most important phenological stage of the mango tree. During this stage, the number of irrigations made to maintain the requisite level of soil moisture was calculated. The fruit splitting percentage was determined using the following formula:

$$\text{Fruit splitting percentage} = \frac{\text{Total fruit splitting on tagged branches}}{\text{Total fruit set}} \times 100$$

Sun scorching on fruit (%) under different moisture levels was calculated by using following formula:

$$\text{Sun Scorching percentage} = \frac{\text{Sun Scorched area}}{\text{Total fruit volume}} \times 100$$

Average fruit volume was calculated and expressed in cubic centimeters. Thirty fruits from tagged branches were used to calculate the average fruit weight, measured with a digital weighing balance. The average yield per tree was then calculated by multiplying the average weight by the number of fruits and expressed in kilograms. Total Soluble Solids (TSS) were determined using a digital refractometer (ATAGO, RS-5000). Before use, the instrument was calibrated with distilled water. The direct reading was noted from the instrument after a drop of mango juice was placed on the prism.

Statistical analysis

The experiment was laid out according to a Randomized Complete Block Design with four treatments, each having five replications. Data were collected for two consecutive years, and the average of both years was calculated. The collected data were statistically analyzed using the analysis of variance (ANOVA) technique, and the LSD test was applied (Jaleel et al., 2021).

RESULTS

Vegetative growth stage after harvest

The effect of different moisture levels during the vegetative growth phase on mango trees was recorded for two consecutive years. It was found that the maximum number of flushes (3.80 cm) was produced by the plants under 35-40% soil moisture, and in plants that were kept under control (2.00 cm), while it remained the minimum in plants under 25-30% soil moisture (Figure 2). It was observed that the plants at the maximum level of soil moisture produced excessive vegetative growth compared to the minimum level of soil moisture. The plants under control treatment (T4), which were irrigated under dry friable conditions according to conventional practice, also behaved similarly to plants kept at T1 soil moisture. From the results, it can be concluded that 35-40% soil moisture (T1) is sufficient to obtain the optimum vegetative flushes per year, essential for the fruiting of the successive year.

As for the length of the mature leaf, it was recorded as maximum under T1 (29.36 cm), followed by T2 (29.06 cm), while it remained minimum under T3 (Figure 3). Similarly, the width of the leaves also followed the same sequence, recording the maximum at 35-40% moisture levels (6.36 cm) and in the control treatment (6.32 cm), while it remained the minimum under 25-30% moisture levels (5.56 cm) (Figure 4).

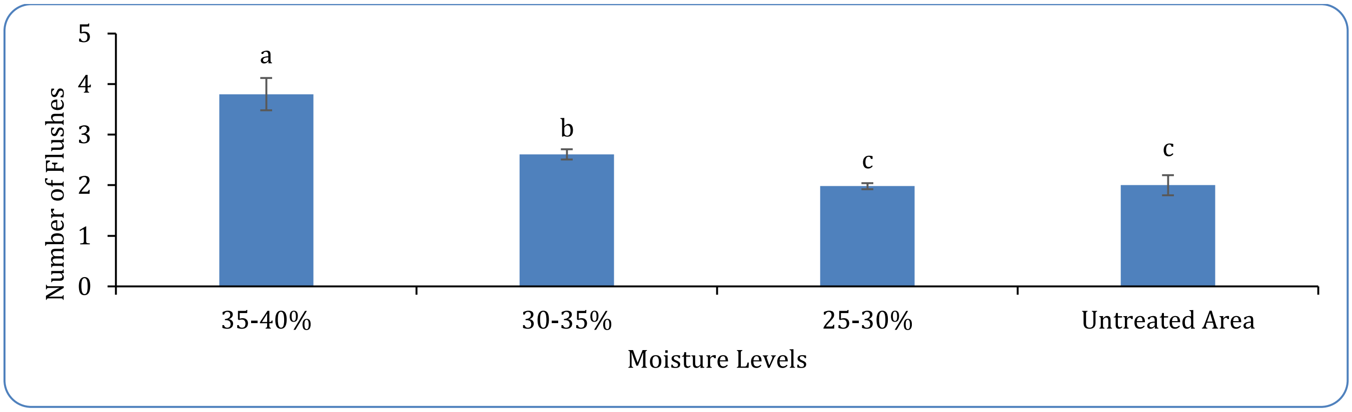

Figure 2: Effect of different moisture levels on number of flushes. Mean values followed by a common letter do not differ statistically (P ≤ 0.05).

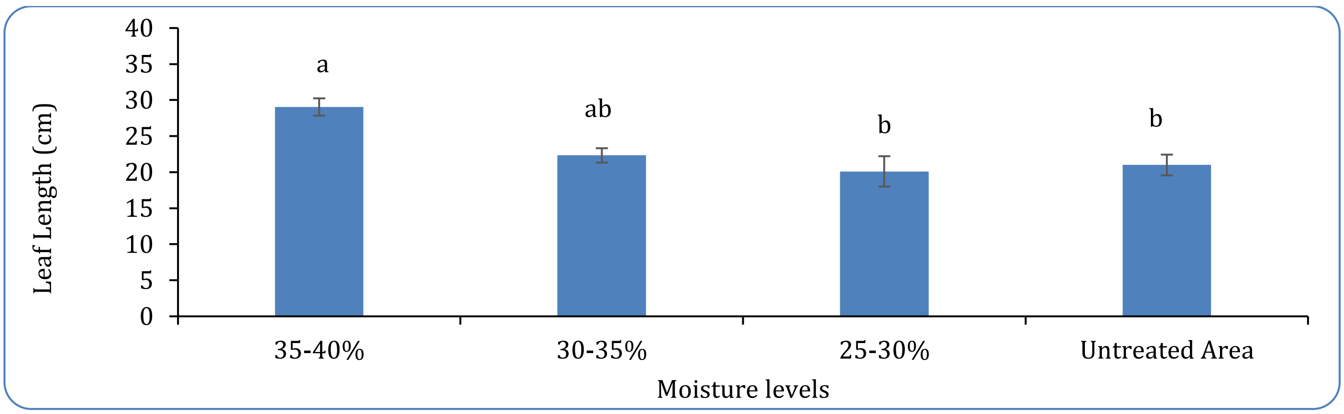

Figure 3: Effect of different moisture levels on leaf length. Mean values followed by a common letter do not differ statistically (P ≤ 0.05).

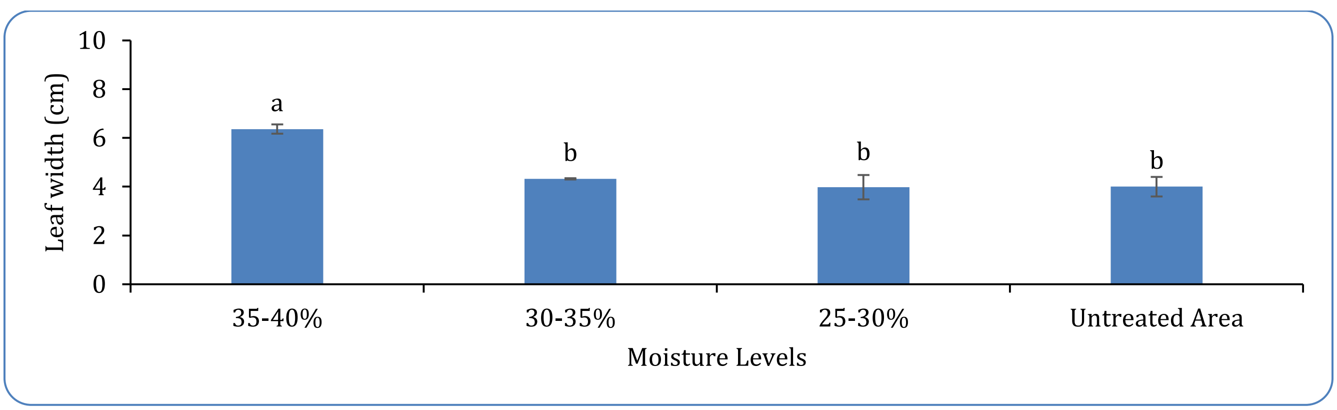

Figure 4: Effect of different moisture levels on leaf width. Mean values followed by a common letter do not differ statistically (P ≤ 0.05).

It has been observed that 40% of irrigations have been saved under T3 compared to T1 and T4. Therefore, T3 remained the most economical compared to the other treatments (Figure 2).

Frost injury

During the winter, maximum frost injury (37%) was observed in plants treated at the 25-30% moisture level, followed by (31%) frost injury in plants that were subjected to the 30-35% moisture level. On the other hand, frost injury was significantly reduced in plants (21%) that were treated at 35-40% moisture levels, followed by control (24%). Controlled irrigation strategies apparently reduced the incidence of frost injury in mango orchards during the cold periods of the year. Furthermore, it has been observed that minimal frost damage was recorded during (2020-21 and 2021-22) under all treatments because the weather remained mostly foggy (Figure 5).

Flowering and fruit setting stage

During the flowering and fruit-setting period, it was recorded that the maximum number of irrigations were made under 35-40% (2), 30-35% moisture level (2), and control treatment (2), while it remained minimum under 25-30% moisture level (1). Thus, T3 remained the most economical compared to the other treatments. The time of flowering was recorded based on visual observation. It was noticed that flowering initiated 3 days earlier under T3 (25-30% moisture level) compared to the rest of the treatments.

The data regarding the average length of the panicle showed that it remained maximum under control (37.96 cm), followed by 35-40% moisture level (37.38 cm) and 30-35% moisture level (35.48 cm), while it was recorded lowest under 25-30% moisture level (31.88 cm). Therefore, it can be said that all the soil moisture levels under the study are equally effective in producing flowering panicles of sufficient length to bear fruit, and no tendency of undersized panicles has been observed, even in the plants at 35-40% soil moisture level (T1).

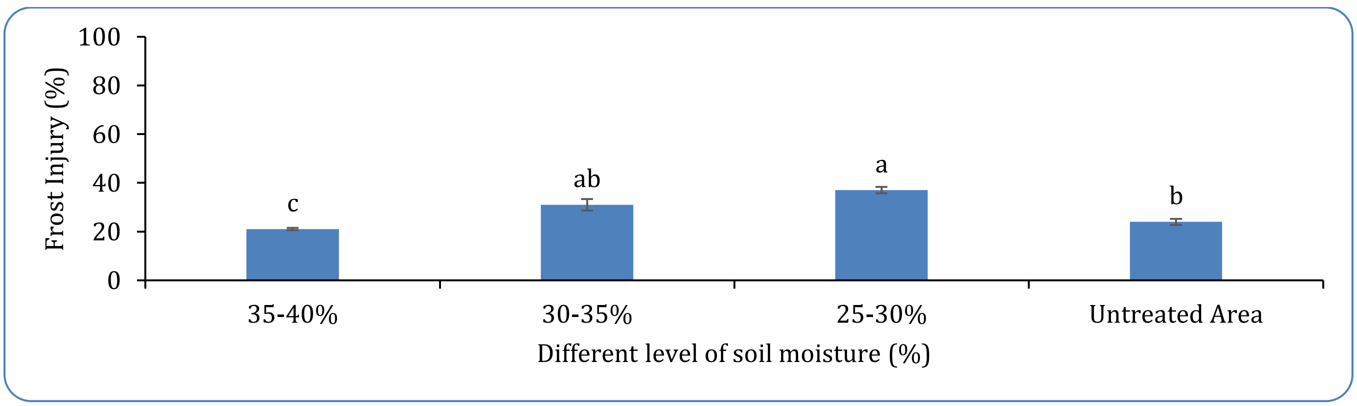

Figure 5: Impact of different soil moisture levels to minimize the frost injury in mango tree. Mean values followed by a common letter do not differ statistically (P ≤ 0.05).

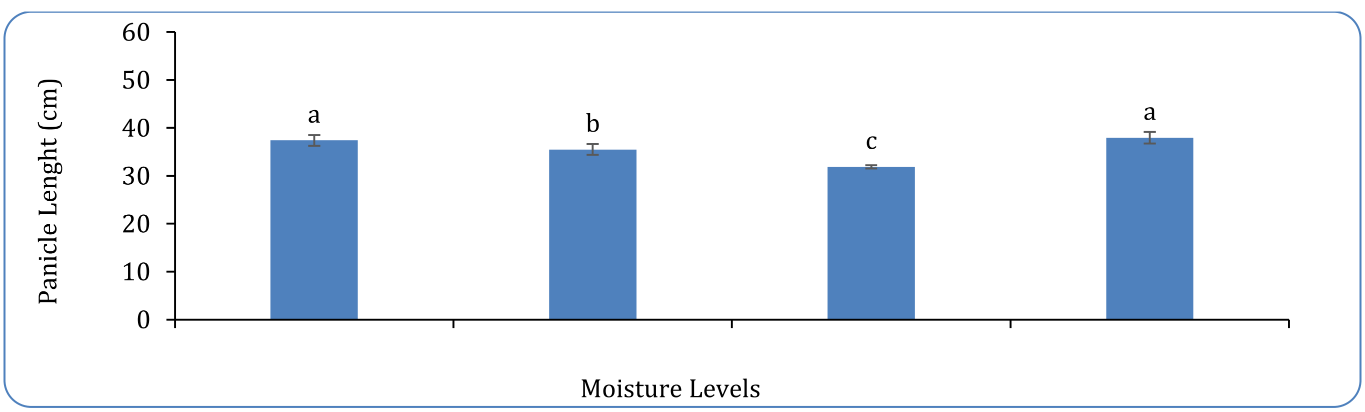

Figure 6: Effect of different moisture levels on panicle length. Mean values followed by a common letter do not differ statistically (P≤0.05).

Fruit development up to harvest

During the fruit development up to harvesting, the maximum number of irrigations were made under T1 (11) and T4 (11), followed by T2 (9), while it remained minimum under T3 (7) (Table 2). Concerning the average number of irrigations made during the years 2018-19 and 2019-20 (Table 3), it was recorded that the maximum occurred with 20 irrigations under T1 (35-40% moisture level) and T4 (control), followed by 30-35% moisture level (16), while the minimum number of irrigations was made under T3 (25-30% moisture level) (12). This data emphasizes that soil moisture at different phenological stages of mango is critical and has an impact on various traits. Regarding fruit splitting (%), it was recorded that only 1.10% fruit splitting was found under T3 (25-30% moisture level), while it remained minimum under T4 (0.68). However, no sun scorching on the fruits was recorded under any treatment (Table 3).

The data concerning the average volume of the fruit (cm^3) (Table 3) showed that the fruits of maximum volume were harvested at 35-40% soil moisture level (583.6 cm^3), followed by the control treatment (566.2 cm^3) and 30-35% soil moisture level (562.6 cm^3), while it was recorded at a minimum under 25-30% soil moisture (498.6 cm^3). Thus, it can be said that all moisture levels are equally effective in meeting the water use potential of the plants to produce fruits of good and acceptable volume.

Table 2: Number of irrigations required to maintain different soil moisture in clay loam soil.

	T1 (35-40%)	T2 (30-35%)	T3 (25-30%)	T4 (DF)
Vegetative growth stage after harvest	5	4	3	5
Flowering & fruit setting stage	2	2	1	2
Fruit development up to harvest	11	9	7	11
Total	20	16	12	20

Table 3: Effect of different moisture levels on different parameters in fruit development and harvest stage.

Parameter	T1	T2	T3	T4
No. of irrigations made	11	9	7	11
Fruit splitting (%)	0.76	1.06	1.10	0.68
Sun scorching on fruit (%)	0.00	0.00	0.00	0.00
Av. volume of fruit (cm3)	583.6	562.6	498.6	566.2
Av. yield per plant (kg)	230	228	211	217
Total soluble solids of fruit (°Brix)	18.0	18.2	19.2	18.0

The data regarding the average yield per plant (kg) showed that the plants under T1 produced the maximum yield (230 kg), followed by T2 (228 kg) and T4 (217 kg), while it was the minimum under T3 (211 kg). The minor difference in yield under T3 compared to the rest of the treatments might be due to the volume of fruit conceived by different levels of soil moisture utilization (Table 3).

The data regarding the total soluble solids of the fruit (°Brix) depicted that TSS remained maximum under T3 (19.2 °Brix) recorded after ripening of the fruit, followed by T2 (18.2 °Brix), while it remained minimum under T1 (18.0 °Brix) and T4 (18.0 °Brix). It shows that at 25-30% soil moisture level (T3), sweetness of the fruit has been found significant amongst all the treatments (Table 3).

DISSCUSSION

It is crucial to comprehend the impacts of water use reduction in the most appropriate and effective manner to address water resource scarcity globally. Countries like India, seeking development across various sectors of life, require numerous techniques to overcome the lack of infrastructure and technology for the long-term effectiveness of schemes (Koley, 2022).

Despite being a crop that can withstand drought, mangoes require optimal water utilization for successful crop production. An adequate amount of water is crucial at the points of cell division, enlargement, fruit growth, and development (Liu et al., 2007). This study investigates the effects of various soil moisture levels on the vegetative and reproductive performance of mango. For effective irrigation management, knowledge of the relationship between mango yield, fruit quality, and water use efficiency is helpful. Throughout the fruit growth cycle with one growth peak, fruit growth is slow at the early stage, expands quickly during the rapidly expanding stage, and slows down at the mature stage. Soil water content is a crucial factor for the early growth of mango fruit. Maximum yield and quality fruit were obtained from trees subjected to 65-70% field water moisture capacity. Total soluble solids, sugars, and ascorbic acid contents also improved under the same treatment (Wei et al., 2017).

Water availability is particularly important during the first 42 days of fruit growth; drought may cause late-stage fruit to fall and lower fruit mass by reducing cell size and quantity (Singh, 2005). Irrigation significantly impacts vegetative growth and fruit development (Liu et al., 2007; Caspari et al., 1994). Irrigation and soil moisture content had a substantial effect on fruit weight when irrigation was stopped 2-3 weeks before the final harvest (Iniesta et al., 2009). A decrease in fruit weight was recorded by stopping irrigation before the final harvest of the mango crop (Diczbalis et al., 1993). Similar results were recorded in cv. Kensington Pride trees, reporting that fruit weight and yield are affected by different soil moisture concentrations (Kuppelwiesser, 1990; Simmons et al., 1995). In the present study, a significant effect of soil moisture changes on flowering, fruit setting, and the yield of mango plants was observed. The maximum yield was recorded under 35-40% soil moisture level.

The effect of irrigation and soil moisture on fruit weight is more evident during the final fruit growth (FFG) phonological period compared to the main fruit growth (MFG) period (Cui et al., 2009). A noticeable difference in various soil moisture levels on fruit weight was observed when irrigation was stopped 2-3 weeks before harvest (Diczbalis et al., 1993).

In the present study, it was observed that plants at the maximum level of soil moisture produced excessive vegetative growth compared to the minimum level where very little vegetative growth was recorded. Previously, it has been reported that reduced irrigations to fruit crops ultimately reduce the induction of vegetative growth in plants (Romero et al., 2004a; Iniesta et al., 2009). Deficit irrigation during different phenological stages of mango also reduces the leaf area index, resulting in less photosynthesis, ultimately reducing the final yield of mango plants; however, enhanced water use efficiency at the yield stage enhances the fruiting capacity (Simmons et al., 1998).

CONCLUSION

In conclusion, it can be asserted that at the 35-40% soil moisture level, the plants have demonstrated favorable outcomes compared to the rest of the treatments, particularly in terms of vegetative growth, fruit volume, yield per plant, and total soluble solids of the fruit. Significant irrigation savings were also observed at the 30-35% and 25-30% soil moisture levels.

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AUTHORS' CONTRIBUTIONS

MI, AN, MAQ, MAB, KS, NS, WM conceived and designed the study; AN collected the data; AN and WJ analyzed the data; AN, MI, and WJ wrote the manuscript; BA, LA, MFAK, ANM, WJ supervised the work and proofread the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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