



Research Article

Effect of Mulching and Drip Irrigation on Water Use Efficiency and Vegetative Growth of Mango under Small Tree System

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Abstract

Mango orchards in Pakistan are mostly irrigated using the basin flood method. A considerable quantity of water is lost from basins and channels through evaporation and seepage. During 2020-21, a study was conducted at Mango Small tree system located in MNS University of Agriculture Multan to examine the effect of drip irrigation systems flow rate and mulching in a split-plot design with two treatments and four replications. Main plot treatments consisted of four drip irrigation systems: Loop, single line drippers, bubbler and double line drippers. Moreover, subplots comprised two levels of mulching: no mulch and organic mulch (hay grass). The plants were irrigated by Drip irrigation on daily basis through Loop drippers of two liters per hour liter per hour (lph), single online line drippers of four lph, bubbler of two hundred lph and double online drippers of four lph discharge capacity from November to March. The drip system at a flow rate of four lph and treated with organic mulch recorded the maximum water use efficiency ($6.46 \text{ kg ha}^{-1} \text{ mm}^{-1}$), stomatal conductance ($140, 25 \text{ mmol}^{-1} \text{ m}^{-2} \text{ s}^{-1}$), sub stomatal conductance ($65 \text{ mmol}^{-1} \text{ m}^{-2} \text{ s}^{-1}$), leaf photosynthetic rate ($6.11 \text{ mmol}^{-1} \text{ m}^{-2} \text{ s}^{-1}$) and leaf transpiration rate ($1.84 \text{ mg m}^{-2} \text{ s}^{-1}$). The plant height and scion girth did not show significant differences with changes in water flow rate and organic mulches. The maximum soil temperature (38° C) was recorded in the non-mulched plot. The application of organic mulches not only enhanced the water use efficiency (WUE) and transpiration rate but also improved chlorophyll contents and the number of flushes.

Keywords: canopy, weeds control, water management, irrigation efficiency, moisture conservation



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Introduction

The mango (*Mangifera indica* L.) is most important fruit crop in Pakistan, and it belongs to the Anacardiaceae family. In Pakistan Mango orchards comprise 0.3 thousand hectares in NWFP, 1.4 thousand hectares in Baluchistan, 50.0 thousand hectares in Sindh, and 104.9 thousand hectares in Punjab (Zahid et al., 2022). The core Mango producing areas of Pakistan include Multan, Bahawalpur, Dera Ismail Khan, Hyderabad, Khanewal Sahiwal,

Muzaffar Garh, Sadiqabad, Rahim Yar Khan, Thatta, and Vehari, The availability of cultivable land is decreasing in Pakistan due to the mismanagement of land and urbanization (Anwar et al., 2022). The cutting rate of Mango trees is increasing continuously to fulfil the needs of humans. However, the area under Mango cultivation decreases daily, reducing mango fruit production (Hahn et al., 2022). Mango productivity is low due to ageing and widely spaced orchards, low-yielding cultivars, poor orchard management, and Pakistani growers' insufficient technological up-gradation and adaptation. Excessive flushes are also produced in tall trees that use the stored carbohydrate, resulting in lower and irregular growth, reducing biennial yield (Smith & Samach, 2013). The high density plantation (HDP) and small tree system (STS) introduced a planting technique in which more plants are grown per unit area. However, HDP is an important technique for achieving high productivity (Ladaniya et al., 2020). Furthermore, drip irrigation in a HDP-STs is beneficial to improve water use efficiency (WUE) and proper fertilizer use through fertigation. The ultimate goal is to adopt this technique to attain high and export quality mango fruit yield (Campbell & Wasielewski, 2000). The spacing for HDP methods implemented is 3 m 2.5 m or 2.5 m 2.0 m, where the plant density is improved by reducing the row spacing, allowing for more trees per acre. On the other side organic mulching is critical for urban soil nutrient conservation and regeneration. It is an effective tool for altering soil structure, essential to ensure that these ecosystems work effectively. Organic mulching adds nutrients and carbon to the Soil and its physical impacts, such as water conservation and temperature control. The study was conducted in the mango small tree system of MNS University of Agriculture, Multan, to determine the Impact of mulching and drip irrigation on water use efficiency (WUE) and vegetative growth of mango.

Material and Methods

Site Description

The experiment was conducted in Mango Small Tree System (MSTS) in MNS University of Agriculture, Multan, Punjab Province, Pakistan (30.146180° N, 71.443833° E). The region has a typical semi-arid climate with an annual temperature of 32° C and maximum temperature of 51° C in June and July with an average rainfall of 175mm. The soil at the experimental site is clay loam. This STS is the first established orchard in Pakistan, however the mango were transplanted in 2020 and 2021 with a density of 570 plants per acre (3 m between plants and 10 m between rows).

Experimental Design

The experiment was laid down in a split-plot design in the randomized complete block design (RCBD) with four replications during 2020 and 21. This experiment was conducted on four varieties, Summer Bahesht (SB) Chounsa, Ratol 12 number, Sufaid Chounsa and Sensation. The main plots were four drip systems (i) Loop system (ii) online single line drippers system (iii) online double line drippers system (iv) bubbler system and the subplot were two (a) without organic mulching (b) organic mulching. The area of each plot was 240ft² (16.24ft by 16.244ft). Each plot consisted of six rows and the plants in each treatment were tagged for the measurements. The four-drip system were set at the flow rate of loop system: 18 liter per hour(lph), online single line drippers system: 64 lph, online

double line drippers system: 64 lph, bubbler system: 200 lph and rice straw was used as an organic mulch. The treatments began with new flushes growth period and ended at the time mango dormancy. Irrigation was carried out on daily basis as well as precipitation events. Moreover, the strips of drip irrigation system were laid along basin of each plant. The diameter of the drip strip was 16 mm and the distance of emitters was set as per plant to plant distance. The fertigation was carried out by the venturi in drip system to control fertigation with irrigation (Phocaidés & Nations, 2007).

Data Collection and Measurement

Data collection

Experimental data was recorded after 30 days to evaluate the best growth of mango plants. Following parameters of eighty selected plants were recorded.

Physiological Attributes

Physiological parameters

Instantaneous Water Use Efficiency ($\text{kg ha}^{-1}\text{mm}^{-1}$), Stomatal conductance (gs), Substomatal conductance (gi), leaf to air-vapour pressure (kpa), Leaf Photosynthesis (A) and Leaf Transpiration rate and were measured by using CIRUS-3.

$$\text{Intrinsic water use efficiency} = \frac{P_n}{g_s} \text{ (Condon, 2020).}$$

It's the proportion of net photosynthesis to transpiration. It is calculated using the formula above.

$$\text{Instantaneous water use efficiency} = \frac{P_n}{E} \text{ (Condon, 2020)}$$

It's the proportion of net photosynthesis to transpiration. It is calculated using the formula above. Quick water use efficiency is calculated directly from CIRUS-3.

Plant Attributes

Growth parameters including leaf area (m^2), plant height(cm), stem girth(mm), number of flushes per plant, leaf fresh weight (g), chlorophyll (SPAD Value) and leaf dry weight (g) were measured after 2 months of organic mulch application. The samples were collected at the interval of one month after the first sampling. A few parameters like plant height, stem grith, number of flushes per plant and were measured at the standing plant however fresh and dry weight of plant and leaf area measured at the laboratory. The collected samples dried and prepared as per guidelines of ICARDA manual to determine Nitrogen (N), Phosphorus (P) and Potassium (K) (Michelini et al., 2012); (Valdés Illán et al., 2012;Randriamanana et al., 2012).

Soil Attributes

Soil samples were collected before and after application mulches. The sample were collected from two (0-30cm and 30-60cm) different depth with the help of soil auger. After collection samples were shifted to the laboratory or further process. The EC (dSm^{-1}) and pH of soil measured by EC, pH meter and organic matter was measured by following Walkley black method. Moreover, the samples for nutrient analysis were prepared by following ICARDA manual and N, P, K analysis were performed (Sui et al., 2022).

Table 1. Physiochemical analysis of soil.

Date	Drip system	EC (dS m ⁻¹)	pH	TDS (ppt)
30/11/2020	Loop	0.15	9.83	0.07
	Single line	0.15	9.73	0.07
	Bubbler	0.13	9.73	0.08
	Double line	0.15	9.82	0.07
30/12/2020	Loop	0.27	9.75	0.14
	Single line	0.30	9.77	0.15
	Bubbler	0.29	9.78	0.15
	Double line	0.30	9.77	0.15
30/1/2021	Loop	0.6	9.65	0.03
	Single line	0.8	9.67	0.04
	Bubbler	0.7	9.66	0.04
	Double line	0.8	9.67	0.04
30/2/2021	Loop	0.8	9.72	0.04
	Single line	0.8	9.88	0.04
	bubbler	0.8	9.96	0.04
	Double line	0.8	9.89	0.04

Effect of Frost on Mortality Rate (%)

The effect of frost on mortality was measured by counting the no. of plants in each zone during the month of December to February (Hmnam et al., 2022). The percentage of mortality rate was measured by the formula:

$$\text{mortality rate \%} = \frac{\text{no. of dead plants}}{\text{total no. of plants}} \times 100$$

Statistical analysis

Statistix 10.0 was used to analyze the data (ANOVA) using RCBD design with Split Plot arrangement at a 5% probability level. Each treatment was replicated four times according to the treatment plan (Ryan and Morgan, 2007).

Results

Physiological Attributes

Instantaneous Water Use Efficiency (kg ha⁻¹mm⁻¹)

Analysis of data indicates a significant difference between the control and treated plot (Figure 1.). The mean comparison shows that maximum water use efficiency was recorded in treated blocks as ($P < 0.05$). In mulched treated Zone 4 (Double line drip system) with a Flow rate of four lph, the maximum water use efficiency (WUE) was recorded (6.47 kg ha⁻¹mm⁻¹). In non-mulched treated Zone 3 (bubbler drip system) with a flow rate of 200 lph, the minimum water use efficiency (WUE) was recorded (2.92 kg ha⁻¹mm⁻¹).

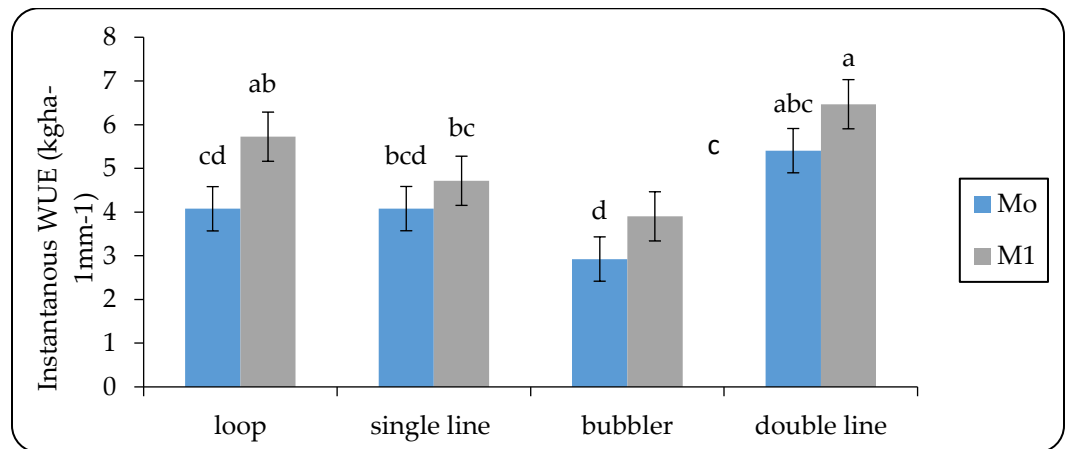


Figure 1. Effect of mulching and drip irrigation on instantaneous water use efficiency (kg ha⁻¹mm⁻¹).

Stomatal Conductance (gs)

Data analysis suggests a significant difference between the treated and control plot (Figure 2a). A mean comparison shows that maximum Stomatal Conductance was recorded in treated blocks as ($P < 0.05$). Mean comparison for Stomatal Conductance showed that the maximum Stomatal Conductance was recorded (140.25) in mulched treated zone 4. Minimum stomatal conductance was recorded (113.5) in mulched treated Zone 1.

Substomatal Conductance (gi)

Data analysis suggests a significant difference between the treated and control plot (Figure 2b). The mean comparison shows that maximum sub-stomatal conductance was recorded in treated blocks as ($P < 0.05$). Mean comparison for sub-Stomatal Conductance showed that the maximum Stomatal Conductance was recorded (64.25) in mulched treated zone 1 and minimum sub-stomatal conductance was recorded (55) in non-mulched treated Zone 1.

Leaf-to-Air Vapor Pressure Deficit (VPD)

Analysis of data suggests that the significant difference in the treated and control plot (Figure 3a). Mean comparison shows that maximum leaf to air vapor pressure deficit was recorded in treated blocks as ($P < 0.05$). Mean comparison for leaf to air vapor pressure deficit showed that the maximum pressure was recorded (3.8588 kpa) in mulched treated zone 2, however minimum was recorded (2.9925 kpa) in non-mulched treated Zone 1.

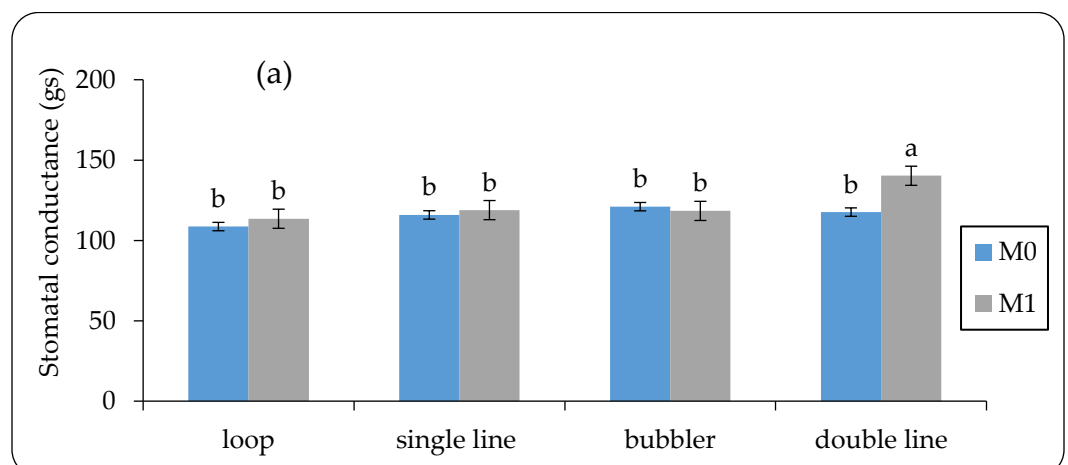


Figure 2. (a) Effect of mulching and drip irrigation systems on stomatal conductance

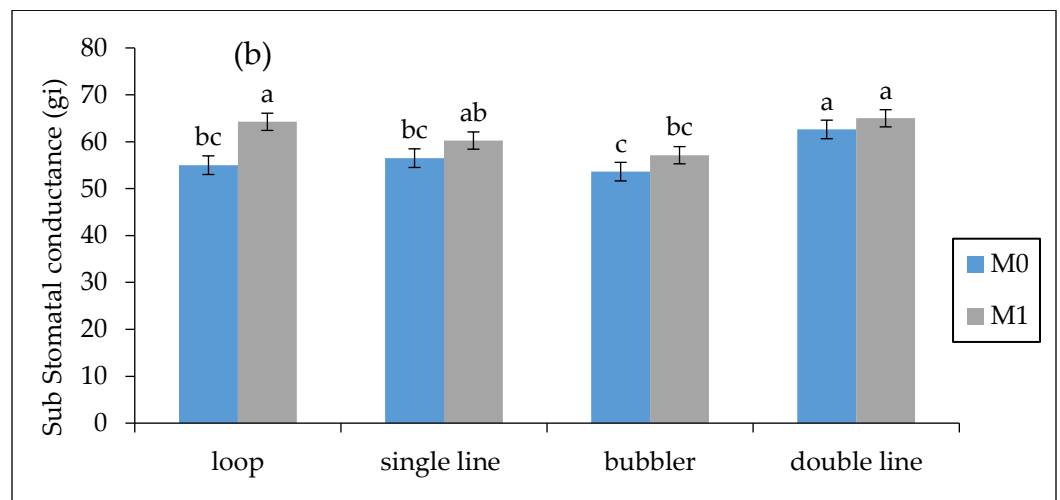


Figure 2. (b) Effect of mulching and drip irrigation systems on substomatal conductance.

Leaf photosynthetic rate (A)

Analysis of data suggests that the significant difference in the treated and control plot (Figure 3b). Mean comparison shows that maximum leaf to air vapor pressure deficit was recorded in treated blocks as ($P < 0.05$). Mean comparison for leaf photosynthetic rate showed that the maximum photosynthetic rate was recorded (6.1125) in non-mulched treated zone 3 and mulched treated zone 4. A minimum photosynthetic rate deficit was recorded (4.4) in non-mulched treated Zone 1.

Leaf transpiration rate (E)

Analysis of data indicates that there is a significant difference between the control and treated plot (Figure 3c). The mean comparison shows that maximum Leaf Transpiration rates were recorded in treated blocks as ($P < 0.05$). Mean comparison for Leaf Transpiration Rate showed that the maximum Leaf Transpiration Rate was recorded (1.845) in mulched treated zone 4 and minimum Leaf Transpiration Rate was recorded (1.2975) in zone 3.

Plant Attributes

Leaf area (m²)

Analysis of data indicates that there is a significant difference between the control and treated plot (Figure 4). The mean comparison shows that the maximum Leaf area was recorded in treated blocks as ($P < 0.05$). Mean comparison for Leaf area showed that the maximum Leaf area was recorded (228.39 m²) in mulched treated zone 4. The minimum Leaf area was recorded (182.65 m²) in zone 3, treated with the non-mulched plot. Mango plant leaf area non significantly affected by various drip irrigation types, mulching while significantly affected by interaction drip irrigation type and mulch. The mango plants irrigated with three drip systems, Loop, single line, and double line drip type systems, comparatively and statistically have greater leaf area than the bubbler drip type system. The non-mulch-treated mango plants obtained the highest plant leaf area compared to mulch-treated plants. The maximum plant leaf area (222.74 m²) was recorded in the double-line drip type system, and the minimum plant leaf area of (194.38 m²) was observed in the bubbler drip type system.

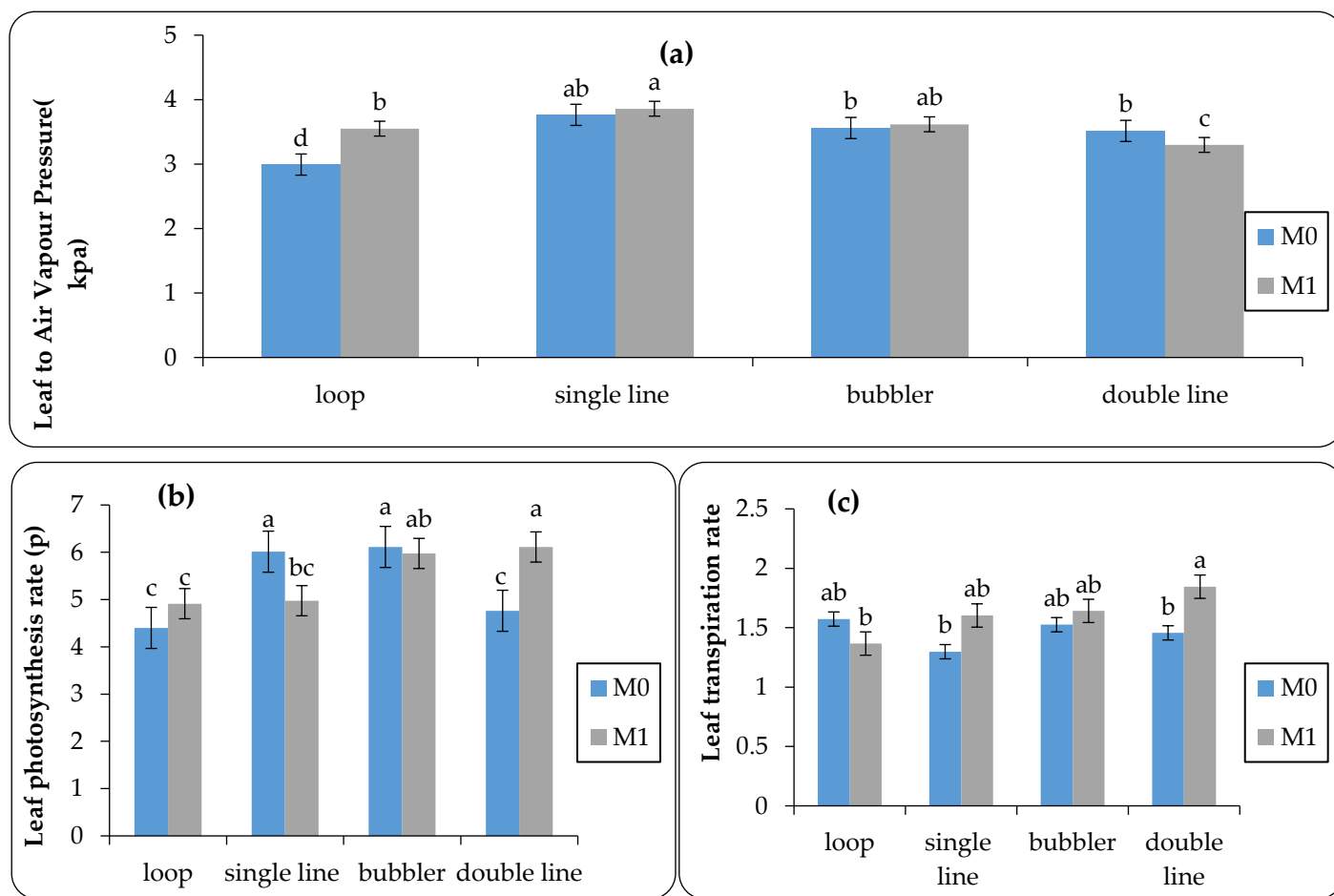


Figure 3. (a) Effect of mulching and drip irrigation systems on Leaf air vapor pressure deficit (b) Effect of mulching and drip irrigation on the leaf photosynthesis rate (c) Impact of mulching and drip systems on leaf transpiration rate.

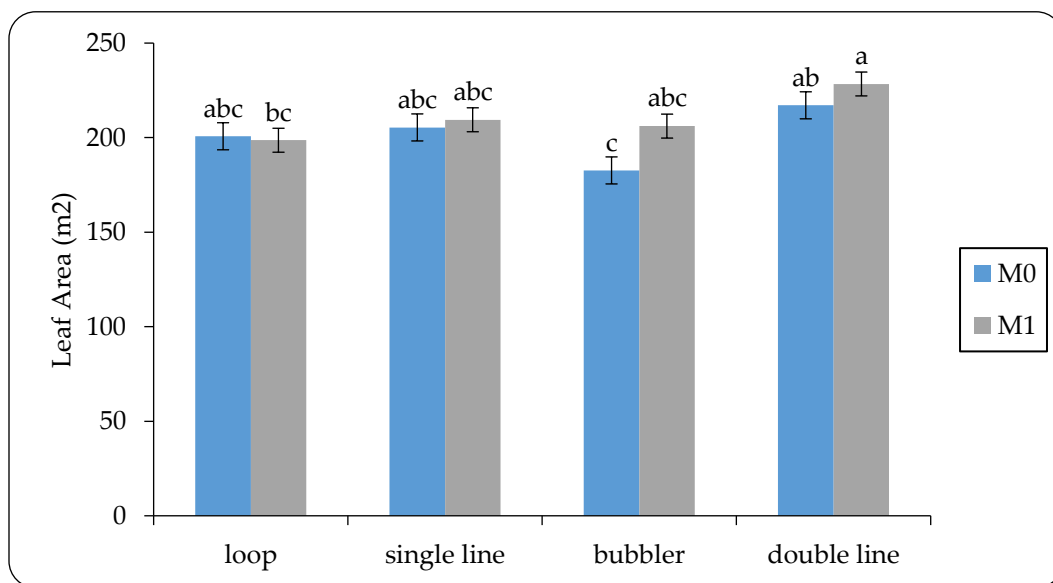


Figure 4. Effect of mulching and drip systems on leaf Area.

Plant height (cm)

Mango plant height non significantly affected by various drip irrigation types, mulching while significantly affected by the interaction between drip irrigation type and mulch

(Table 2). Compared to non-mulched treated mango plants, mulched treated plants had the highest plant height. The maximum plant height in a Zone 1 was 139.94 cm, whereas, in a Zone 4 the minimum plant height was 124.88 cm was recorded. Mango plants irrigated with Loop drip type, single line drip type, and double line drip type systems comparatively and statistically affect equally mango plant height as compared to the bubbler system. The maximum plant height of 143.75 cm was observed in the single-line drip-type system, and the minimum plant height of 129.63 cm was observed in the bubbler drip-type system. The height of mango plants according to drip irrigation type affected none significantly. Mulching significantly affected mango plant height after 90 days of the interval by interaction with drip irrigation type and mulch. Irrigation with three drip systems, Loop, single line, and double line drip type systems, comparatively and statistically affects plant height equally compared to the bubbler drip type system. Compared to non-mulched treated mango plants, mulched treated plants were the tallest. The maximum plant height in a single-line drip-type system was 148.19 cm, whereas, in a bubbler drip-type system, the minimum plant height was 137.56 cm.

Table 2. Effect of various drip irrigation systems and mulch on plant height of mango.

Irrigation types	Mulch	Non-Mulch	Mean
After one month, Nov 2020			
Loop system	140.13 a	135.63 a	137.88 a
Single line system	144.38 a	135.50 a	139.94 a
babbler system	134.88 a	114.88 a	124.88 b
Double line system	142.75 a	135.63 a	139.19 a
Mean	140.53 a	130.41 b	
After two-month Dec 2020			
Loop system	145.50 a	139.50 a	142.50 a
Single line system	148.63 a	138.88 a	143.75 a
babbler system	138.63 a	120.63 b	129.63 b
Double line system	146.63 a	139.63 a	143.13 a
Mean	144.84 a	134.66 b	
After three-month Jan 2021			
Loop system	150.63 a	143.75 ab	147.19 a
Single line system	151.75 a	142.25 ab	147.00 a
babbler system	142.63 ab	132.50 b	137.56 a
Double line system	149.25 a	147.13 ab	148.19 a
Mean	148.56 a	141.41 b	
After four-month Feb 2021			
Loop system	154.88 a	148.50 ab	151.69 a
Single line system	155.38 a	145.00 ab	150.19 a
babbler system	146.13 ab	137.25 b	141.69 a
Double line system	152.88 a	151.75 ab	152.31 a
Mean	152.31 a	145.63 b	

Plant girth (mm)

Mango plant girth was not significantly affected by various drip irrigation types, mulching while significantly affected by interaction drip irrigation type and mulch

(Table 3). Mango plants irrigated with three drip systems, Loop, single line, and double line drip type systems, comparatively and statistically show greater girth than the bubbler drip type system. The mulched-treated mango plants obtained the highest plant girth as compared to none mulched-treated plants. The maximum plant girth of 86.875 mm was recorded in the loop drip type system, and the minimum plant girth 69.375 mm was observed in the bubbler drip type system. Various drip irrigation types affected none significantly while mulching significantly affected the plant girth of mango after 60 days of the interval by interaction with drip irrigation type and mulch. Irrigated plants of mango with Loop, single line drip type, and double line drip type systems comparatively and statistically affect mango plant girth equally compared to the bubbler system. The maximum plant girth of 96.875 mm was observed in the loop drip type system, and the minimum plant girth was 78.750 mm in the bubbler drip type system. The girth of mango plants according to drip irrigation type is not significantly affected, while mulching of grass hay significantly affects mango plant girth after 90 days of interval by interaction drip irrigation type and mulch. Mango plants irrigated with three drip systems, Loop, single line, and double line drip type systems comparatively and statistically obtained higher plant girth as compared to bubbler drip type system. The mulch treated mango plants obtained the highest plant girth as compared to non-mulch treated plants. The maximum plant girth 111.25 mm was recorded in loop drip type system and minimum plant girth 87.50 mm was observed in bubbler drip type system. Mulching effect significantly on mango plant girth while, different drip irrigation types of effect on significantly on mango plant girth after 120 days of interval by interaction drip irrigation type and mulch. Three drip systems, Loop, single line, and double line drip type systems comparatively and statistically effect equally on plant girth as compared to bubbler drip type system. The mulch treated mango plants obtained the highest plant girth as compared to non- mulch treated plants. The maximum plant girth 122.50 mm was recorded in loop drip type system and minimum plant girth 88.75 mm was observed in bubbler drip type system.

Table 3. Effect of various drip irrigation types and mulch on plant girth of mango.

Irrigation types	Mulch	Non-Mulch	Mean
After one month Nov 2020			
Loop system	86.250 a	87.500 a	86.875 a
Single line system	88.750 a	76.250 a	82.500 a
bubbler system	71.250 a	67.500 a	69.375 a
Double line system	80.000 a	80.000 a	80.000 a
Mean	81.563 a	77.812 a	
After two-month Dec 2020			
Loop system	100.00 a	93.75 ab	96.875 a
Single line system	103.75 a	78.75 b	91.250 a
bubbler system	78.75 b	78.75 b	78.750 a
Double line system	87.50 ab	95.00 ab	91250 a
Mean	92.500 a	86.563 a	
After three-month Jan 2021			
Loop system	116.25 a	106.25 ab	111.25 a

Single line system	115.00 a	85.00 c	100.00 ab
bubbler system	87.50 bc	87.50 bc	87.50 b
Double line system	97.50 abc	105.00 abc	101.25 ab
Mean	104.06 a	95.94 b	
After four-month Feb 2021			
Loop system	128.75 a	116.25 a	122.50 a
Single line system	126.25 a	93.75 b	110.00 a
bubbler system	88.75 b	88.75 b	88.75 b
Double line system	107.50 ab	107.50 ab	107.50 ab
Mean	112.81 a	101.56 b	

Number of flushes

The number of flushes of Mango plants significantly affected by various drip irrigation types, mulching while signification affected by interaction drip irrigation type and mulch (Table 4). Three drip systems, Loop, single line, and double line drip type systems comparatively and statistically effect equally on number of flushes as compared to bubbler drip type system. The mulch treated mango plants obtained the highest number of flushes as compared to non-mulch treated plants. The maximum plant number of flushes were observed in 4.0 was recorded in single line drip type system and loop system collectively and minimum plant number of flushes 2.0 was observed in bubbler drip type system. Various drip irrigation types of effect on significantly, while, mulching significantly affected on plant height of mango after 60 days of interval by interaction drip irrigation type and mulch. Loop, single line drip type, double line drip type system comparatively and statistically effects equally on mango plant number of flushes as compared to bubbler system. The maximum plant number of flushes 6 was observed in single line drip type system and minimum plant height 3 was observed in bubbler drip type system. The number of flushes of mango plant according to drip irrigation type affected none significantly while mulching significantly effect on mango plant growth after 90 days of interval by interaction drip irrigation type and mulch. Three drip systems, Loop, single line, and double line drip type systems comparatively and statistically effect equally on plant number of flushes as compared to bubbler drip type system. The mulch treated mango plants obtained the highest plant height as compared to non-mulch treated plants. The maximum plant number of flushes 6.0 was recorded in single line drip type system and number of flushes 3.0 was observed in bubbler drip type system.

Table 4. Effect of various drip irrigation types and mulch on number of flushes of mango.

Irrigation types	Mulch	Non-Mulch	Mean
After one month Nov 2020			
Loop system	4.0000 ab	2.5000 ab	3.2500 a
Single line system	4.0000 ab	3.8750 ab	3.9375 a
bubbler system	2.0000 b	3.6250 ab	2.8125 a
Double line system	4.3750 a	2.8750 ab	3.6250 a
Mean	3.5938 a	3.2187 a	

After two-month Dec 2020			
Loop system	3.2500 a	4.3750 a	3.8125 a
Single line system	6.0000 a	3.1250 a	4.5625 a
bubbler system	3.0000 a	3.3750 a	3.1875 a
Double line system	5.7500 a	2.8750 a	4.3125 a
Mean	4.5000 a	3.4375 a	
After three-month Jan 2021			
Loop system	3.5000 ab	5.8750 ab	4.6875 ab
Single line system	6.7500 a	5.2500 ab	6.0000 a
bubbler system	3.5000 ab	3.3750 ab	3.4375 b
Double line system	5.7500 ab	2.8750 b	4.3125 ab
Mean	4.8750 a	4.3438 a	
After four-month Feb 2021			
Loop system	2.7500 a	4.0000 a	3.3750 a
Single line system	5.3750 a	3.3750 a	4.3750 a
bubbler system	4.5000 a	3.1250 a	3.8125 a
Double line system	5.2500 a	3.1250 a	4.1875 a
Mean	4.4687 a	3.4063 a	

Chlorophyll Contents

The graph demonstrates that as the leaves get older, their SPAD readings increase. There was a considerable increase in SPAD readings in Double line and loop drip systems. Average values (67.83 SPAD units) in loop drip system and average values (65.94 SPAD units) in double line drip system are increased according to the graph. At bubbler drip type irrigation, however, the SPAD reading reduced to an average of (37.22 SPAD units). The chlorophyll concentration in the leaves is positively linked with the greenness of the leaves as evaluated by the SPAD meter. Figure 5a depicts the SPAD reading of November as it relates to the time interval between the leaves. Average values (66.07 SPAD units) recorded in loop drip system and average values (52.83 SPAD units) recorded in double line drip system. At bubbler drip type irrigation, however, the SPAD reading reduced to an average of (35.69 SPAD units). Figure (5b) depicts the SPAD reading of December as it relates to the time interval between the leaves. Average values (65.13 SPAD units) in loop drip system and average values (60.77 SPAD units) in double line drip system which increased. At bubbler drip type irrigation, however, the SPAD reading reduced to an average of (34.06 SPAD units). Figure (5c) shows the outcome of the SPAD reading January connected to the time interval of the leaves. The maximum Chlorophyll Spad values (69.15 SPAD unit) were found in mulched treated block zone four, which had a flow rate of four liters per hour, and the lowest (41.36 SPAD unit) in the bubbler zone, which had a flow rate of 200 liters per hour. Figure (5d) shows the outcome of the SPAD reading of February with respect to the age of the leaves. The highest value of chlorophyll (70.02 SPAD unit) was recorded in double line drip system, however minimum chlorophyll (32.04 SPAD unit) was recorded in bubbler system.

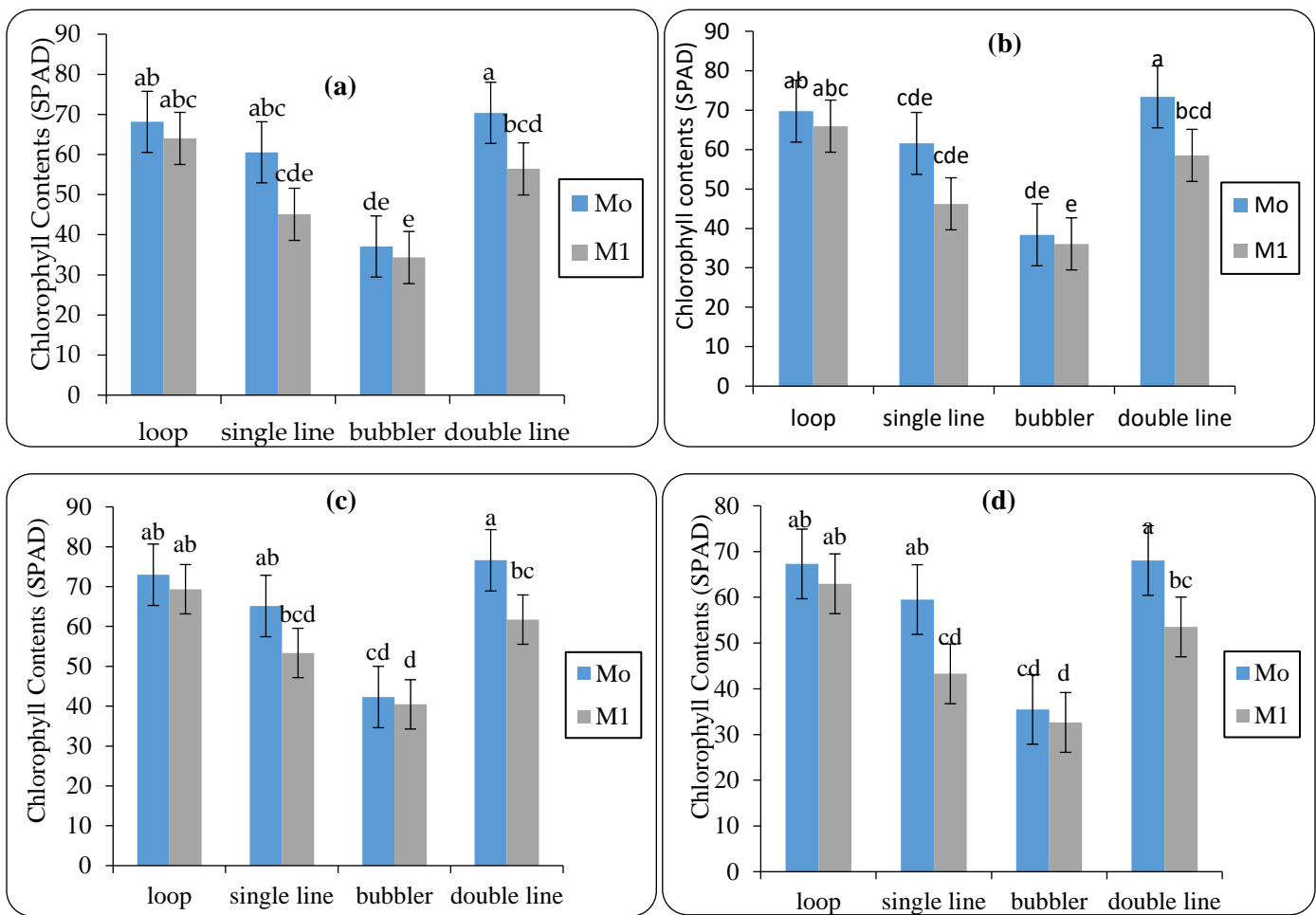


Figure 5. (a) Effect of organic and inorganic mulches on chlorophyll contents of mango plant during and November under small tree system (b) Effect of organic and inorganic mulches on chlorophyll contents of mango plant during and December under small tree system (c) Effect of organic and inorganic mulches on chlorophyll contents of mango plant during and January under small tree system (d) Effect of organic and inorganic mulches on chlorophyll contents of mango plant during and February under small tree system.

Leaf fresh weight and dry weight (g)

Analysis of data indicates that there is a significant difference between the control and treated plot (Figure 6). Mean comparison shows that maximum Leaf fresh weight was recorded in treated blocks as ($P < 0.05$). Mean comparison for Leaf fresh weight showed that the maximum Leaf fresh weight was recorded (9.69 g) in mulched treated zone two. The minimum Leaf fresh weight was recorded (5.82 g) in zone three treated with non-mulched plot. Analysis of data indicates that there is a significant difference between the control and treated plot. Mean comparison shows that maximum Leaf dry weight was recorded in treated blocks as ($P < 0.05$). Mean comparison for dry weight showed that the maximum dry weight was recorded (5.08 g) in mulched treated zone two. Minimum Leaf dry weight was recorded (3.42 g) in zone three treated with non-mulched plot. The Leaf fresh weight showed that the maximum Leaf fresh weight was recorded (9.69 g) in mulched treated zone two and minimum Leaf fresh weight was recorded (5.82 g) in zone three.

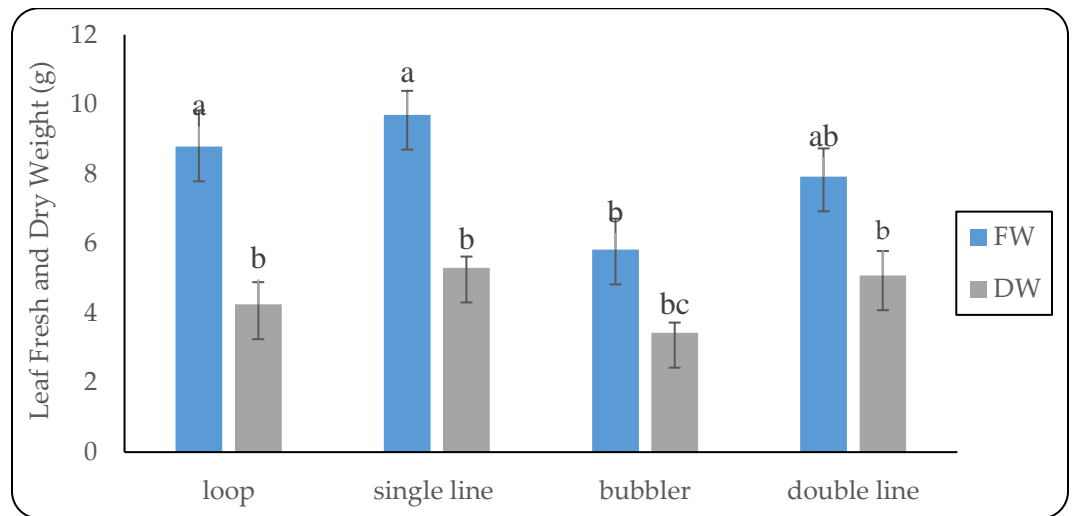


Figure 6. Effect of mulch and drip irrigation systems on fresh and dry weight of mango leaf.

Available Potassium (mg kg^{-1})

Analysis of data indicates that significant difference on the control and treated plot (Figure 7a). Mean comparison shows that maximum available Potassium Content were recorded in treated blocks as ($P < 0.05$). The maximum potassium concentration was recorded ($27.2 \pm 9.22 \text{ mg kg}^{-1}$) in treated block Double line system= flow rate @ 4 lph and minimum available potassium concentration was recorded ($6.95 \pm 0.25 \text{ mg kg}^{-1}$) in bubbler irrigation system in non-treated plot.

Available Phosphorus (mg kg^{-1})

Analysis of data indicates that significant difference on the control and treated plot (Figure 7b). Mean comparison shows that maximum available Phosphorus concentration were recorded in treated blocks as ($P < 0.05$). Mean comparison for available Phosphorus. The maximum Phosphorus concentration was recorded ($0.33 \pm 0.015 \text{ mg kg}^{-1}$) in treated block Double line system flow rate @ 4 lph. The minimum available Potassium concentration was recorded ($0.12 \pm 0.01 \text{ mg kg}^{-1}$) in bubbler irrigation system in mulched block.

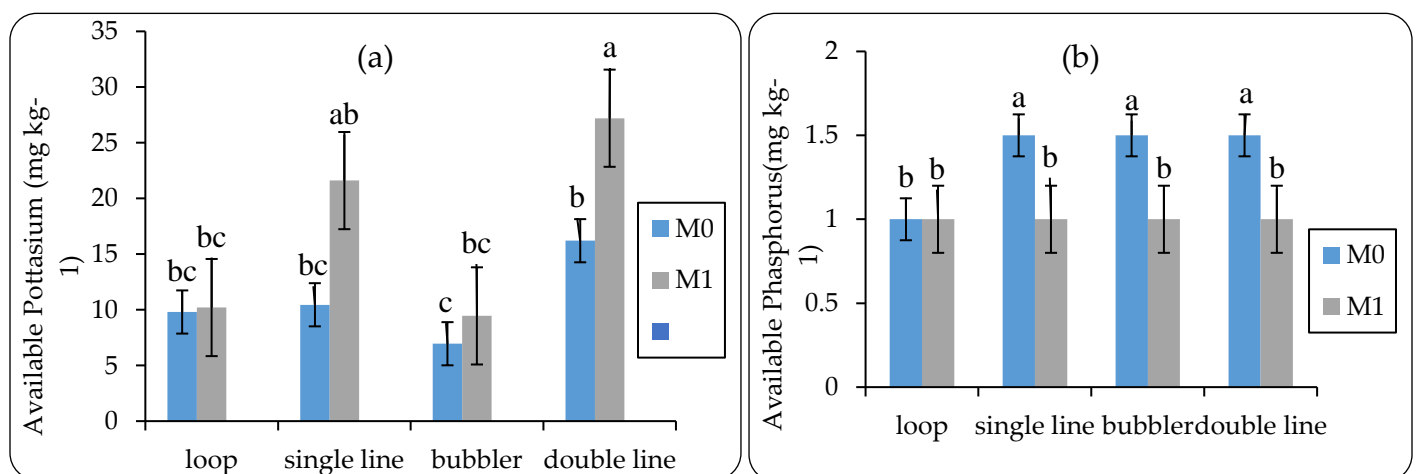


Figure 7. (a) Effect of mulch and drip irrigation systems on available potassium (b) Effect of mulch and drip irrigation systems on available Phosphorus.

Soil Attributes

Soil organic matter (%)

Analysis of data indicate that significant difference on the control and treated plot (Figure 8). Mean comparison shows that maximum organic matter was measured in treated blocks as ($P < 0.05$). The maximum organic matter concentration was measured (0.76 ± 0.015 %) in treated block loop system= flow rate @ 2 lph. Minimum soil organic matter concentration was recorded (0.54 ± 0.02 %) in single line drip irrigation system in mulched block.

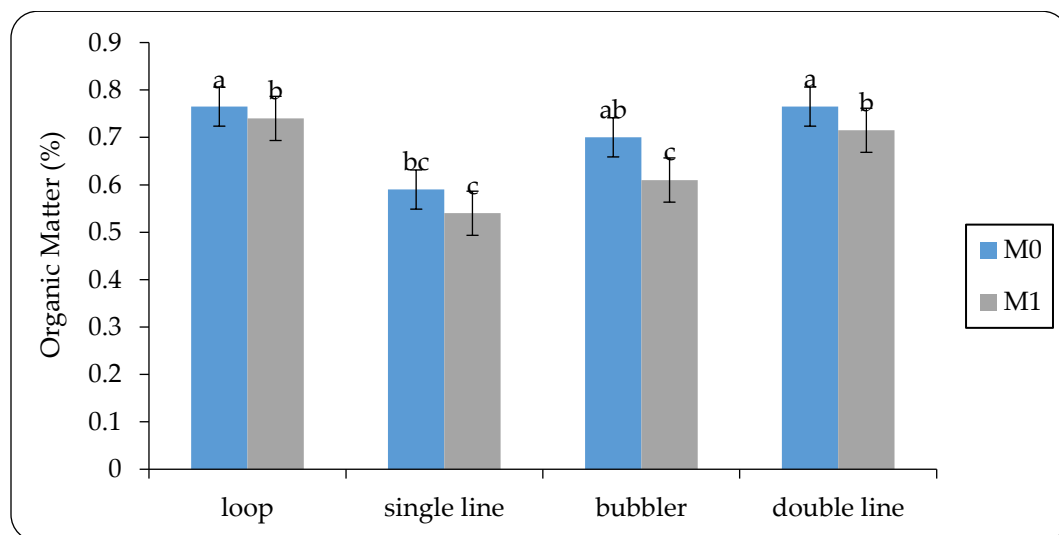


Figure 8. Effect of mulch and drip irrigation systems on soil organic matter.

Available Nitrogen (mg kg^{-1})

Analysis of data indicates that significant difference on the control and treated plot (Figure 9a). Mean comparison shows that maximum available nitrogen content was recorded in treated blocks as ($P < 0.05$). The maximum nitrogen concentration was measured (0.023 ± 0.015 mg kg^{-1}) in treated block loop system flow rate @ 2 lph. Minimum nitrogen concentration was measured (0.048 ± 0.02 mg kg^{-1}) in single line drip irrigation system= mulched block.

Available Phosphorus (mg kg^{-1})

Analysis of data indicates that significant difference on the control and treated plot (Figure 9b). Mean comparison shows that maximum available Phosphorus content were measured in treated blocks as ($P < 0.05$). The maximum Phosphorus concentration was measured (1.5 ± 0.35 mg kg^{-1}) in non-treated block of all drip systems other than loop system and the minimum available Phosphorus concentration was recorded (1 ± 0.25 mg kg^{-1}) in Loop drip irrigation system= non mulched block.

Available potassium (mg kg^{-1})

Analysis of data showed that minimum available Potassium concentration was (77 ± 0.1 mg kg^{-1}) in bubbler irrigation system= non mulched block. Mean comparison shows that maximum available Potassium Content were recorded in treated blocks as ($P < 0.05$). Mean comparison for available Potassium. The maximum Potassium Content concentration was recorded (166 ± 12.03 mg kg^{-1}) in treated block bubbler drip system= flow rate @ 200 lph (Figure 9c).

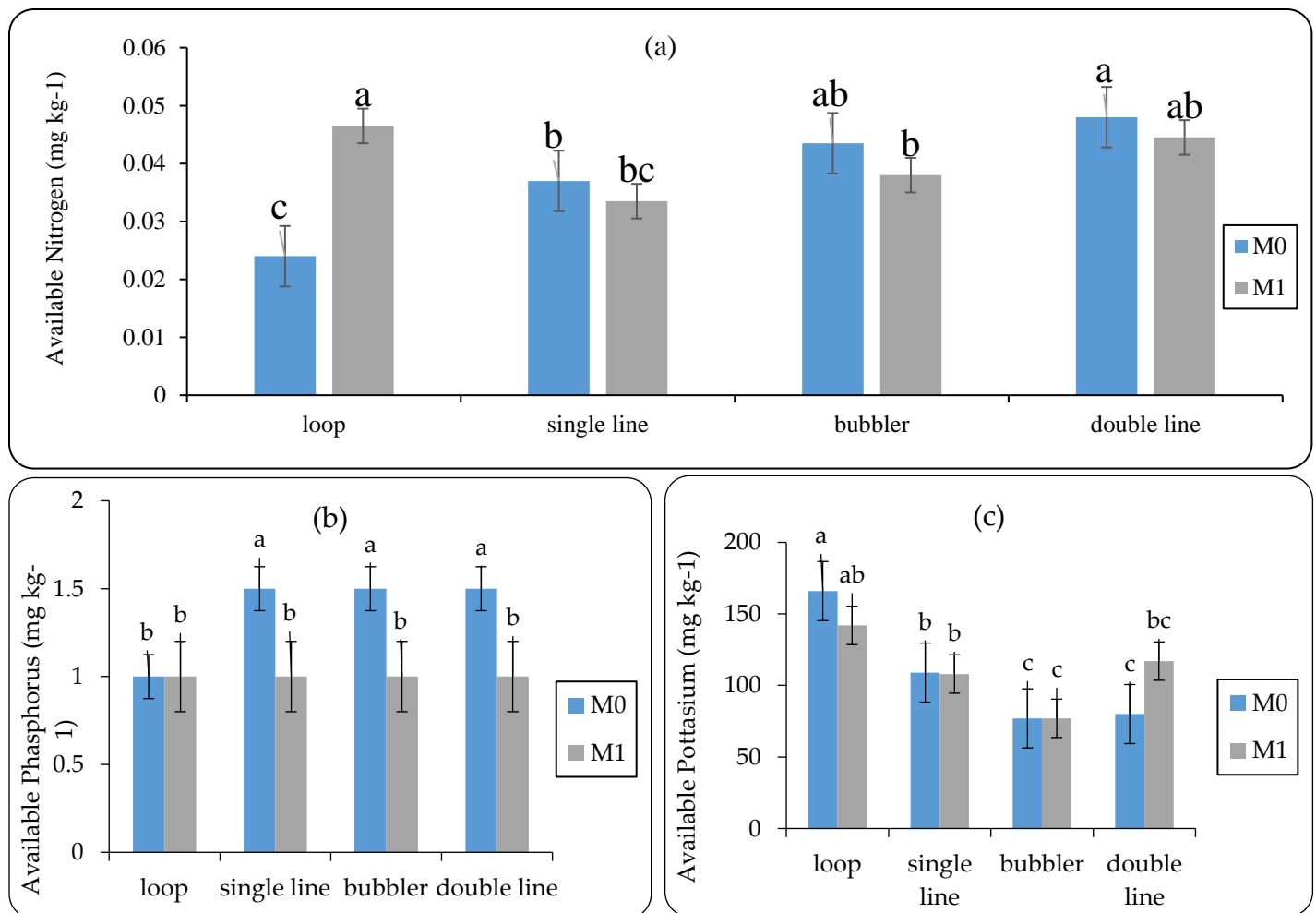


Figure 9. (a) Effect of mulch and drip irrigation systems on available nitrogen (b) Effect of mulch and drip irrigation systems on available Phosphorus (c) Effect of mulch and drip irrigation systems on available potassium.

Soil temperature (°C)

The highest soil temperature values was recorded 38°C in non-mulched treated block loop and single line drip system and lowest (34.75°C) in bubbler zone=flow rate 200 lph. The maximum soil temperature was recorded (36.5°C) in mulched treated block double line system and minimum (34.87°C) in bubbler drip irrigation system in treated block. The result of November (Figure 10a) shows that the highest soil temperature values was recorded (41°C) in non-mulched treated block double line and bubbler drip systems and lowest (39.7°C) in bubbler zone=flow rate 200 lph. The maximum soil temperature was recorded (43.5°C) in mulched treated block double line system and minimum (38°C) in Loop and single line drip irrigation system in treated block. In the month of December (Figure 10b) the highest soil temperature values was recorded (33°C) in non-mulched treated block loop, single line and bubbler drip systems and lowest (32.5°C) in double line drip irrigation system=flow rate 4 lph. The maximum soil temperature was recorded (36.5°C) in mulched treated block double line system and minimum (34.87°C) in bubbler drip irrigation system in treated block. The result of January (Figure 10c) shows that the

highest soil temperature values was recorded (21°C) in non-mulched treated block loop and single line drip systems and lowest (19°C) in bubbler zone=flow rate 200 lph. The maximum soil temperature was recorded (23°C) in mulched treated block double line system and single line and minimum (22°C) in bubbler loop drip irrigation system in treated block (Figure 10d).

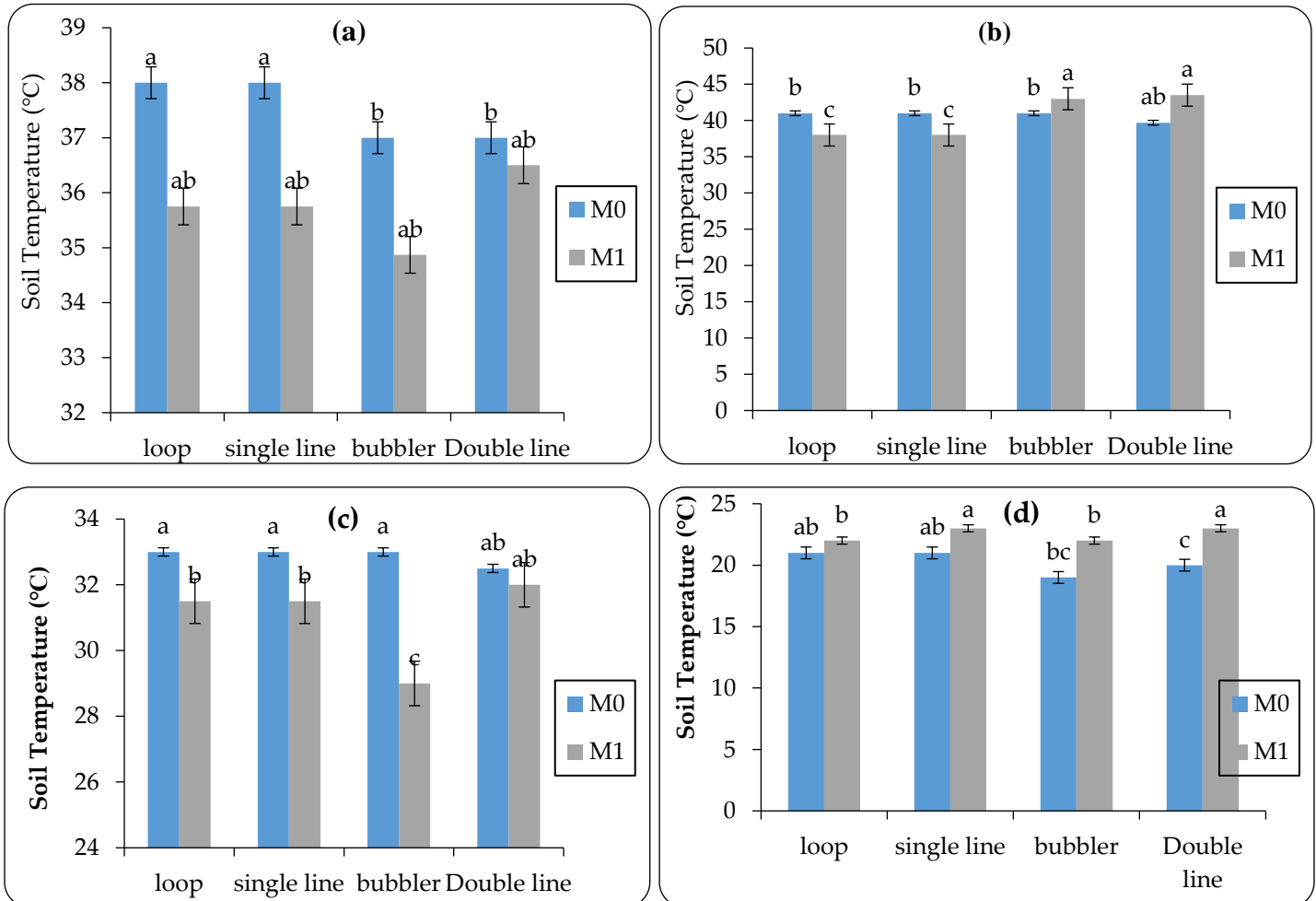


Figure 10. (a) Effect of different types of mulches on soil temperature during November under small tree system (b) Effect of different types of mulches on soil temperature during December under small tree system (c) Effect of different types of mulches on soil temperature during January under small tree system (d) Effect of different types of mulches on soil temperature during February under small tree system.

Effect of Frost on Mortality Rate (%)

The highest mortality rate was recorded (7 plants) plants in mulched treated block of bubbler drip system. and lowest (4 plants) in double line drip irrigation system and single line drip irrigation system was recorded having both the flow rate 16 lph. The maximum mortality rate in non-treated plots was recorded (11 plants) in non-mulched treated block bubbler drip system and minimum (9 plants) in Loop and single line drip irrigation system in non-treated block. The result of frost for the mortality rate was shown in Figure 11.

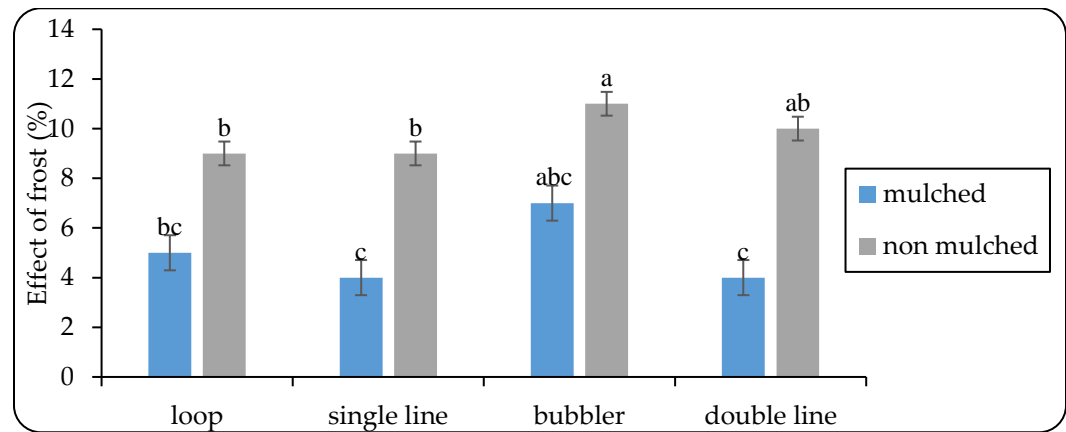


Figure 11. Effect of frost on mortality rate of plants at mango small tree system.

Discussion

Water use efficiency (WUE) is a ratio between two physiological processes (transpiration and photosynthesis or carbon absorption) or agronomic metrics that measures a plant's efficiency in utilizing water (yield and crop water use). In this scenario, there are insufficient water supplies in semi-arid subtropical regions to meet demand, resulting in increased competition among potential consumers (Jones, 2004). Plant growth and water applied were used to calculate the irrigation water consumption efficiency for various treatments (Figure 1). The irrigation water use efficiency in drip irrigation treatments with double line drip type with 4 liter-volume of water with organic mulch was highest (6.46 q/ha-cm), followed by loop drip type irrigation with 2 lph (5.71 q/ha-cm), bubbler (3.90 q/ha-cm), and single line (4.72 q/ha-cm) with four-liter flow rate of water. The bubbler drip type system has the lowest water use efficiency (2.92 q/ha-cm). The water use efficiency of 60 percent water through drip irrigation with organic mulch was about 3.27 times those of surface irrigation treatment. According to (Panigrahi et al., 2019) the largest water application resulted in the lowest water use efficiency. Drip irrigation with a bubbler drip type irrigation system had the best emission uniformity, whereas basin irrigation with a loop irrigation system had the lowest. As the VPD rises, the stomatal conductance of various plant species decreases (Drake et al., 2013). Increased VPD resulted in a decrease in leaf transpiration rate (steady state), which was reversible and independent of leaf water status. As a result, when compared to conventional drip irrigation systems, the double line has a higher stomatal conductance (140.2) and a lower leaf vapor pressure deficit (3.2). Meanwhile, the rate of leaf transpiration is low (1.3), and the VPD is significant (3.55). The reaction of the stomata to VPD is also dependent on the species (Inoue et al., 2021). In high density planting systems, a detailed analysis of vegetative growth pattern was conducted. In the higher density planting system (574 trees ha⁻¹), the maximum tree height was 153, 152.6, and 152.33 cm in the Loop, single line, and double line systems, respectively. In a high density planting system (574 trees ha⁻¹), the minimum tree height is 122, 136, and 136 cm, respectively. (Adak et al., 2019) found that a quality fertigation program improved mango yields by increasing soil organic carbon, accessible P, and K in the topsoil layer (0–30 cm). Table 1 shows the results of the uni-variate statistical study of soil characteristics and foliar nutrients. According to the calculated soil parameters, the soils of high-density

systems (MSTS) had an average pH of 7.2, ranging from 6.9-7.6. With a mean value of 0.38 percent soil organic carbon which is low and below required criteria. Available N, P, and K in the Soil were similarly on the low level, at 0.765, 1 and 80 mg kg⁻¹, respectively. The constant dripping in the area around the main trunk creates excessive soaking, which might lead to root rot/wilt in the long run. This could also lead to root mortality, which would have an impact on fruit quality and yield. It's also worth noting that the drippers are only put near the main trunk, roughly 45 to 60 cm from the stem, causing such wet strains. The placement of the drippers must be considered while building a system. Drip irrigation has the advantage of just irrigating the crop canopy area, leaving the rest of the land uncultivated and dry. Most of the area between mango rows appeared to be relatively dry, limiting weed growth. As a result, the dry soil surface raised temperatures as compared to wet areas irrigated by basins or floods. Also, because the temperatures are very high at this time of year, vapor-transpiration is accelerated, resulting in a rapid difference in moisture gradients between roots and leaves. Due to the severe moisture gradient, the water taken up by the roots does not match the transpiration needs, causing the plant leaves to wilt. The plant leaves were clearly yellow (wilted), especially during the afternoon hours, but they were lush and green in the surrounding basin-irrigated region. When comparing drip irrigated mangoes to basin flooded ones, the leaves of the plants appeared unclean. During the fruiting and maturity phases, the channels should be flooded at least once a month. Once a month, the drip-irrigated plants were washed to eliminate dirt from the leaves, which would aid improve stomatal activity. Most growth characters, however, were significantly altered exclusively by varying levels of drip irrigation, regardless of fertilizer doses applied via drip. The average leaf area rose significantly as a result of the fertilizer dose and its interaction with the irrigation level. This rise could be attributed to improved soil moisture, nutrients, and reduced weed growth as a result of drip irrigation with mulch, as observed by others. Decreases in surface water quality degradation, soil organic matter levels, reduced water infiltration rates, and other soil physical parameters, as well as declines in soil organic matter levels, tree brunch angle, pest protection, and other Soil physical parameters, may have an impact on its lower satisfactory level of production (Adak et al., 2019). According to the findings of this study, high density plantation systems are more productive than traditional farming in terms of yields. The medium density HDP system is the best among the HDP systems and may be recommended to farmers to maintain a reasonable yield level. Based on canopy and fertilizer management, farmers might achieve mango yields of 15–16 t ha⁻¹ or even higher. Nutrient data revealed significant differences in these high-density planting systems. There were also effects of density on soil physical qualities. For increased yields, a robust management system is still required.

Conclusion

Mango orchards in Pakistan are mostly irrigated by the flood method. In this way a considerable quantity of water is wasted. To conserve the water research was conducted to grow mango orchards on the drip irrigation system. In the research four drip irrigation systems, viz., Loop, single line drippers, bubbler and double line drippers. The drip system at flow rate of four (lph) and the plants applied with organic mulch recorded the maximum

water use efficiency, stomatal conductance, sub stomatal conductance, leaf photosynthetic rate and leaf transpiration rate. The plant height and plant scion girth did not show significant differences with change in water flow rate and organic mulches. The maximum soil temperature was recorded in the non-mulched plot. The application of organic mulches not only enhanced the water use efficiency (WUE) and transpiration rate but also improved chlorophyll contents and number of flushes. Thus it is concluded that the establishment of mango orchard on the drip system by the application of organic mulches is recommended for future production.

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Conflict of Interest

The authors declare no conflict of interest.

Author's Contribution

Abid Hussain: Supervised the research and field trials activities. Shakeel Ahmad and Sami Ullah: Assisted in the analysis of different nutrients. Muhammad Naveed, Mohsin Nawaz and Adnan Fareed: Contributed to the writing of this manuscript.

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