COMPARISON OF BUBBLER AND BASIN IRRIGATION METHODS IN A BIVARIETAL *MANGIFERA INDICA* ORCHARD IN PAKISTAN

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ABSTRACT: *Increasing water shortages has compelled to adopt the modern and efficient irrigation methods to enhance crop production. This research aimed to assess the performance of bubbler and basin irrigation methods in terms of water use efficiency, water saving and plant growth parameters of Sindhri and Chaunsa mango varieties. The plot area at experimental site in Sindh Agriculture University, Tandojam, Pakistan was divided into two equal parts, each one 889.87 m^2 for bubbler and basin irrigation methods. Mango plants of both varieties of one year old were transplanted at 12.2 m spacing. The experiment consists complete Block design (RBC) with 2 treatments of 3 replications under each variety. ANOVA was done by applying Tukey test at $p \leq 0.05$. The volume of water in both cases was applied as per crop water requirement. The performance of bubbler irrigation system was satisfactory for what it was designed in terms of distribution uniformity. The distribution uniformity varied by 92.6% for laterals and 93.9% for the entire system. The results revealed that about 30.94% water was saved under bubbler irrigation method as compared to the basin irrigation method. The additional amount of saved water can efficiently be utilized to bring the fallow land under cultivation.*

Keywords: Bubbler irrigation, basin irrigation, plant growth parameters, distribution uniformity.

INTRODUCTIN

The agriculture sector is under tremendous pressure to produce high yields in order to meet food, fiber and fuel requirements. Though this sector contributes about 22 % of Gross Domestic Product in the country [1] but it is still lagging behind. Several major crops like cotton, sugarcane, wheat, rice etc. vegetable crops and fruits provide both the income and employment to growers and exporters [2, 3] but better land and water management are still needed to effectively support sustainable agriculture. The decline of land and water resources [4], and the increasing cost of the production inputs are some of the challenges that need to be properly addressed [5].

Pakistan possesses a contiguous irrigation system ranked 5^{th} in the world and 3^{rd} in Asia and it is known as Indus Basin Irrigation System [6]; however, a huge amount of water is lost in conveyance systems and also at the farm level. Farmers prefer to adopt traditional flood irrigation methods such as border, basin and furrow, and the entire soil surface is flooded without considering the actual crop water requirements hence; water is being lost unnecessarily due to deep percolation [7, 8]. These traditional methods consume more water, are less efficient and must be minimized; at the same time, high efficiency irrigation methods, such as sprinkler, drip or trickle, surface and subsurface drip irrigation, pitcher and bubbler irrigation should be introduced in Pakistan.

In some developing countries, high efficiency micro irrigation methods, such as trickle/drip, bubbler and sprinkler irrigation are now in practice, which save the water and produce high yields [9]. These methods have advantages and disadvantages as one method may be suitable for a set of conditions but inappropriate for others. Therefore, proper selection of an irrigation method is vital for a better management, especially in fruit trees and orchards. Drip irrigation is one of the latest methods of irrigation and it is quite popular in the water scarce areas as it provides high water use efficiency, in an uniformed distribution, water savings, and increased yields. Hassan [10, 11, 12] have listed a number of likely advantages of drip irrigation. Tagar *et al*. [13] compared drip and furrow irrigation methods in a field study conducted at a farmer's field in Umar Kot and observed 56.4% in water saving with drip irrigation. Yields were higher by about 22%, and they showed higher water use efficiency by about 4.87 as compared to that of furrow irrigation method. Ibragimov [14] reported higher yields in the range between 18 and 42% and a water use efficiency in the range between 35 and 103%. While Soomro *et al.*[15] reported water savings by about 70 to 80% as compared to conventional flood irrigation methods.

Bubbler irrigation is a modified version of drip irrigation system for orchard crops; Rawlins [16] reported effective use of bubbler irrigation system in orchards, many other researchers continued the work of improving system design that can be adopted under different areas and conditions [17, 18]. The typical bubbler irrigation system consists of a water source, a pumping unit, a mixing chamber, one mainline, several sublines, some laterals and bubblers, etc. In general, root development under drip irrigation is constrained to the wetted soil volume by the emission points, thereby roots are concentrated near the soil surface and their length is decreased. A poorly designed drip irrigation system does not cover entire canopy and it is unable to provide sufficient moisture around the tree canopy hence plant remains stressed. Mirjat *et al.* [19] observed that the plant growth was almost similar; however, signs of leaf stress were observed under drip irrigated trees, while mango trees irrigated by traditional basin method showed no wilting sign of leaves. Also, local farmers pointed out a better yield in mango trees under basin irrigation as compared to drip irrigation methods.

Thus considering the facts above, this research was conducted to evaluate and compare the performances of bubbler and basin irrigation methods in terms of water savings, water use efficiency and plant growth in an orchard of mango trees of the *Sindhri* and *Chaunsa* varieties.

MATERIALS AND METHODS

Description of the experimental area

The field experiments were conducted at the experimental station located at Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam. The experimental site is located at 25° 25' 28" N and 68° 32' 25" E; about 26 m above the mean sea level. The one-year-old mango plants were transplanted during 2012-2013 to this site in a 1.5 ha area. A plot measuring 1781 m^2 was delimited in this experimental study. Mango plants were irrigated with traditional and micro irrigation systems established with the financial assistant of Higher Education Commission, Pakistan. The research plot was divided into two equal subplots each measuring 890 m^2 area and irrigated by bubbler and basin irrigation method. The two varieties of mango *i.e.* '*Sindhri*' and '*Chaunsa*' were selected in this study because they are suitable according to local climatic conditions and have commercial value in local and international market.

Design of bubbler irrigation

Bubbler irrigation was designed according to the guidelines provided by Nakayama [20, 21]. The layout plan of bubbler irrigation system is illustrated in Figure 1. The design intends the modification of basin irrigation for plants to prevent this type of area increasing in the future as it is the usual practice in conventional irrigation methods. The land preparation, plant spacing, irrigation scheduling and other agro-chemical practices for young mango plant were applied in the bubbler irrigation plot design according to the guide lines by MINFAL [22].

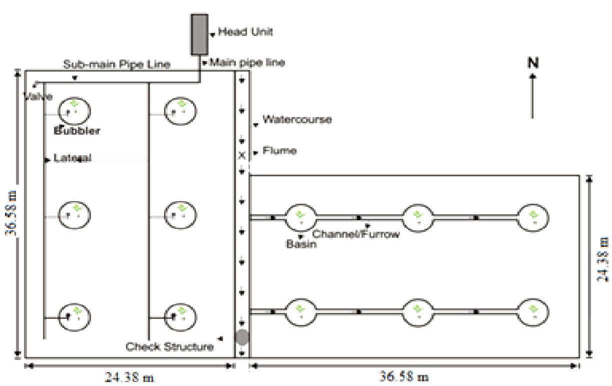

Figure 1: Experimental field layout

Measurement of soil physical properties

Soil samples were collected at 0-15, 15-30, 30-45, 45-60, 60-75, 75-90 and 90-105 cm depths before experimentation at three randomly selected locations under each treatment. The samples were also collected at three randomly selected locations around the trunk of mango plants at similar depths after mango plantation. The samples collected for a given depth were mixed to yield a composite sample and soil textural class was determined.

Bouyoucous Hygrometer method was used to determine the soil textural class [23] while, double-ring infiltrometer was used to determine the infiltration rates of soil in the vicinity of experimental plots. Dry bulk density was calculated using the equation given by Mcintyre [24] similarly, field capacity and soil porosity was calculated using following equation by Kanwar [25].

$$Dry\ \text{bulk density}\ (\rho\partial) = \frac{\text{Dry weight of soil}}{\text{Total volme of soil}} \times 100 \ \ldots\ldots\ldots \text{(i)}$$

$$Field\ \text{Capacity} = \frac{\text{Weight of water in certain vol. f soil}}{\text{Weight of the same volume of soil}} \times 100 \ \ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

$$Soil\ \text{porosity} = \left(1 - \frac{\text{Dry Bulk Density of soil}}{\text{Particle density}}\right) \times 100 \ldots \text{(iii)}$$

Water samples were collected to determine the quality of irrigation water (groundwater). Chemical properties such as Electrical Conductivity (EC_w) was measured using conductivity meter, pH with pH meter and Sodium Absorption Ratio (SAR) were determined using standard procedures adopted by Rowell [26].

Depth and frequency of irrigation

Water is consumed by plants through their roots and it is therefore necessary that sufficient moisture is available in the root zone depth. The irrigation scheduling is based on the soil moisture depletion. In this study, 50% soil moisture depletion was fixed and next irrigation was applied when soil moisture deficit attained this criterion [22]. Soil samples were collected at the basins under basin irrigated plots and in the vicinity of emission point under bubbler irrigated plots and soil moisture contents were determined. Soil moisture content was determined by oven drying the soil sample for 24 h at a temperature of 105°C and was calculated by using appropriate equation. Tensiometers were installed to measure the soil moisture deficit. Once soil has attained the desired deficit, irrigation was applied to bring it at the field capacity. The irrigation depths were calculated using equation given by Soomro *et al.* [27]:

$$D = \frac{\text{SMD}}{100} \text{ x pb x dr} \qquad (4)$$

$$SMD = \theta_f - \theta_o \qquad (5)$$

$$\theta = \frac{(W_w - W_d)}{W_d} \text{ x } 100 \qquad (6)$$

Where,

D = Depth of water required (cm)
SMD = Soil moisture deficit level
pb = Bulk density (grams cm^{-3})
dr = 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)

W_d = Oven dry weight of soil (g)

Irrigation water measurements for bubbler and basin irrigation methods

The volume of water required under bubbler irrigation was measured through a flow meter installed in the mainline. While, the depth of water required under basin irrigation was measured using a cut throat flume installed at the head of channel. The time required to supply the required depth was calculated by equation given by Soomro *et al.* [27]. In case, if any precipitation occurred during study period it was recorded and subtracted from the total volume water applied under both irrigation methods.

$$QT = 28 \text{ x A x D} \quad (7)$$

where;

Q = discharge required (LPS)
T = time of application (hour)
A = area to be irrigated (hectare)
D = depth of irrigation to be applied (cm)

Measurement of water distribution uniformity under bubbler irrigation

The volume of water under each bubbler was measured and uniformity of water application was determined. The containers were placed underneath each emission point and water flowing through a bubbler, for a given time, was collected. After a given time interval, the flow was disconnected and the containers were removed. The volume of water collected in each container was measured using a graduated cylinder. The recorded volume was divided by time to yield the discharge at each bubbler. The measured discharge was used to calculate the uniformity coefficient and distribution uniformity using the equations given by ASAE [28, 29, 30, 13].

$$C_u = 100 - \left(80 - \frac{S_d}{V_{avg}} \right) \quad (8)$$

$$Cv = \frac{\sigma}{V_{avg}} \text{ x } 100 \quad (9)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (V_{LQ} - V_{avg})^2}{n}} \quad (10)$$

$$D_u = 100 \left(\frac{V_{LQ}}{V_{avg}} \right) \quad (11)$$

Where,

$C_u =$ Uniformity coefficient (%)
$V_{avg} =$ Average volume collected
$S_d =$ Standard deviation of observations
σ = Standard deviation
$Cv =$ Uniformity variation (%)
$V_{avg} =$ Average volume collected.
$V_{LQ} =$ Average of the lowest ¼ volume of water collected
$D_u =$ Distribution uniformity %

Water saving estimation

Water saving was determined by dividing difference in water used by bubbler over basin irrigation methods. This procedure has been adopted by Tagar *et al.* [13]:

$$W.S = \frac{W_a - W_b}{W_a} \times 100 \quad (12)$$

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).

Measurement of plant growth parameters

The mango plants were randomly selected and tagged for measurements. The plant height (cm), stem girth (cm), and numbers of branches per plant were recorded on monthly basis. The measurements continued for two years. The measurement procedure described by Abdou *et al.* [31] was followed. The experiment consists complete Block design with 2 treatments of 3 replications under each variety. ANOVA was done by applying Tukey test at $p \leq 0.05$.

RESULTS AND DISCUSSION

The performance of two irrigation methods *i.e.* basin irrigation and bubbler irrigation has been evaluated and their impact on soil various physical properties such as soil texture, dry bulk density, porosity, infiltration rate and field capacity has been assessed.

Soil physical properties

The study area remained fallow/ barren for the last ten years; hence variation in soil physical properties is expected due to cultural practices and mode of irrigation. Results did not suggest any change in the soil texture. The soil was classified as clay loam before experimentation and it remained same after experimentation under both irrigation methods. The average dry bulk density was 1.17g cm^{-3} before experimentation and mango transplantation. However, after one year of mango plantation, the average dry bulk density increased to 1.23g cm^{-3} under bubbler irrigation and 1.25g cm^{-3} basin irrigation methods (Table 1). Variation in soil bulk density was non-significant under two irrigation methods. These results are similar to those reported by Magesan *et al*. [32] who reported that the physical property effected by irrigation application.

The average porosity before experimentation and mango transplantation was 54%. Its values slightly decreased from 54% to 52% under bubbler irrigation and from 54% to 49% under basin irrigation (Table 1). The porosity was higher under bubbler irrigation as compared to basin irrigation method. The preparation of basins around the plants had altered the soil structure which in turn had changed its porosity. During irrigation, basins are ponded with water that might have affected the porosity under this method. Almost similar results have been reported by Roberta *et al.* [33]. They reported that the irrigation application with groundwater and waste water led to reduction in micro porosity of the soil.

Table 1. Dry bulk density ($\rho\partial$), Field capacity, Soil porosity (η) and Infiltration rate before and after experiment

Sr. No.	Soil Properties	Before Experiment	After Experiment	
			Bubbler Irrigation plot	Basin Irrigation Plot
1	Average dry bulk density (ρ_d) gcm^{-3}	1.17	1.23	1.25
2	Average field capacity (%)	35	34.8	34.5
3	Average porosity (η) %	54	52	49
4	Average infiltration rate ($mmhr^{-1}$)	8	7.2	6.05

Table 2. Irrigation water quality of the experiment

Source of water	Water quality parameters		
Tube Well	EC (micro-S/cm)	pH	SAR
(Groundwater)	1361	7.7	6.72

The infiltration rate of the soil was determined before experimentation and it was found as 8 mm/hr. The infiltration rate was significantly affected by irrigation treatments. It decreased to 7.2 mm/hr under bubbler irrigation and decreased to 6.05 mm/hr under basin irrigation method (Table 1) after one year of experimentation. The decrease in infiltration rate is attributed to application of marginal quality groundwater. At the soil surface, infiltration rate was particularly sensitive to soil salinity and sodium absorption ratio. Oster and Jayawardane [34] reported that the infiltration rate and hydraulic conductivity decreased with soil salinity and increasing exchangeable sodium. The statistical analysis of the data reveals that the soil dry bulk density, porosity, and infiltration rate were significantly affected under both irrigation methods. However, the interaction between irrigation treatment and mango varieties was insignificant. The soil physical properties and irrigation did not affect the mango growth.

The field capacity of soil was determined before experimentation and turn to be 35%. It slightly decreased to 34.8% around mango plant trunk irrigated through bubbler irrigation method, whereas it deceased to 34.5% around mango plant trunk irrigated through basin irrigation method. The reduction in soil field capacity is expected due to soil compaction after experiment under both irrigation methods. The results shown in Table 5 reveal that the field capacity varied only by 0.2% under bubbler irrigation method and by about 0.5% under basin irrigation method.

Quality of Irrigation Water

The quality of irrigation water significantly affects soil physical properties. Poor quality water results in salinity buildup in the root zone and that ultimately reduces plant growth. The groundwater was applied to mango planted irrigated under bubbler and basin irrigation methods. The quality of irrigation water was defined in terms of pH, EC and SAR value and the results values are presented in Table 2. The analysis of data reveals that the water can be termed as good quality water (EC_w< 1500 µS/cm, SAR < 10) and can be applied directly without any danger provided that all other soil and management practices are observed properly.

Weather related parameters and irrigation frequency

Appendix-1 shows air temperature, relative humidity, pan evaporation and rain fall occurred during experimental period. A four day irrigation application interval was used in the bubbler and basin irrigation methods during the research period. However, the quantity of irrigation water varied according to available soil moisture. Equation 5 was used to calculate the volume of irrigation water required.

Irrigation volumes applied and water saved

There are several techniques used to determine the irrigation schedules which are based on plant, soil and weather parameters. In this research, the irrigation schedules were set to 50% depletion as suggested by MINFAL [22]. The water consumed under both irrigation methods and water saved under bubbler irrigation method are illustrated in Figure 6. A total of depth of 1239.213 mm was applied to all 6 plants irrigated by bubble irrigation method against 1794.37 mm applied in the basin irrigation method. This suggests that 30.94% was saved under bubbler irrigation as compared to basin irrigation method. The findings of this research are in agreement with those of other researchers. A significant amount of water was saved under drip irrigated crops as compared to those irrigated under traditional irrigation methods [35, 36, 37, 15, 13].

Water Application Uniformity of Bubbler Irrigation System

The main objective of bubbler irrigation method is that water must be applied uniformly, so that each plant receives same amount of water. If irrigation were not applied uniformly, some plants would receive more water and others will remain stressed. As a result, plant growth would be non-uniform, and water will be wasted where it is excessively applied. Uniformity of irrigation water is important especially, where agro-chemicals are mixed with the irrigation water. The uniformity of water application from a bubbler irrigation system is affected by the water pressure distribution in the pipe network, hydraulic properties of the bubbler used, and quality of irrigation water. The values of the application uniformity are based on the values of uniformity coefficient (Cu), coefficient of variation (Cv) and distribution uniformity (Du). The values of these parameters were calculated and the results are summarized in Table 4.3. Al-Amoud [38] who reported the uniformity of distribution of bubbler system was low with drip irrigation system which is in contradiction to our results. These results suggest that the system can be rated from good to excellent i.e. satisfactory as mentioned by ASAE [28].

Table 3. Minimum discharge, Average discharge, Standard deviation, Coefficient of variation, Uniformity coefficient and Distribution uniformity

Sr.No	Minimum discharge q_m (lit/hr)	Average discharge q_{avg}	$\Sigma(q - q_{av})^2$	Standard deviation σ	Coefficient of variation (Cv)	Uniformity coefficient (Cu)	Distribution uniformity (Du)
Lateral 1	99.924	107.002	142.491	4.873	4.554	96.357	93.916
Lateral 2	95.382	105.223	206.470	5.866	5.575	95.540	92.590
Entire System	95.382	106.112	176.330	3.833	3.612	97.110	92.599

Plant growth traits

The plant growth parameters, such as plant height, stem girth and numbers of branches per plant under bubbler and basin irrigation methods were measured on monthly basis for the *Sindhri* and *Chaunsa* varieties. The mango plant growth parameters gradually increased with time. Figures 2 to 5 clearly show that there was slight change in plant growth parameters measured between November, 2012 and February, 2013. However, after March 2013 mango plants showed a significant growth. Increase in the plant height and mango stem girth was more pronounced under Bubbler irrigation method as compared to basin irrigation method, while change in plant height was significantly affected by the mango variety. During the study period, the average increase in *Sindhri* mango height varied between 52.66 and 60.00 cm, while increase in *Chaunsa* plant varied between 45.33 and 46.00 cm under the both the irrigation methods. Similarly, the average increase in stem girth of *Sindhri* varied between 2.1 and 3.3 mm and for *Chaunsa* it varied between 3.8 and 3.9 mm. The average increase in the number of branches varied between 2.33 and 3.33. Analysis of Variance (ANOVA) showed that the values of mango growth parameters were non-significant to each other.

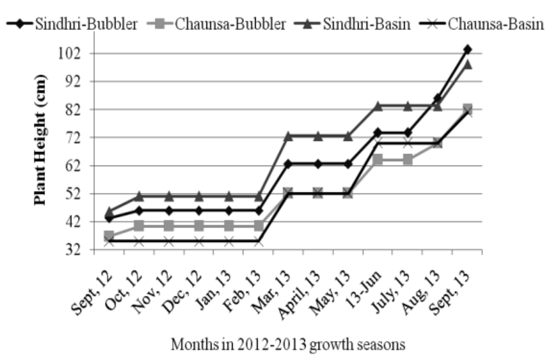

Figure 2: Increments in plant height per month

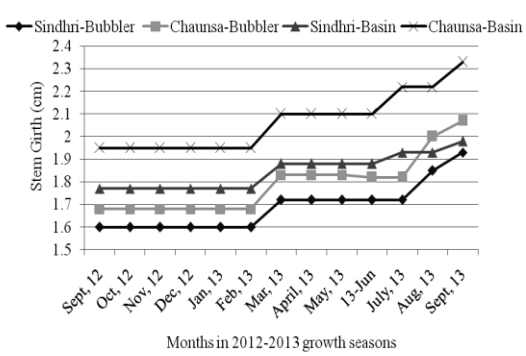

Figure 3: Increments in stem girth per month

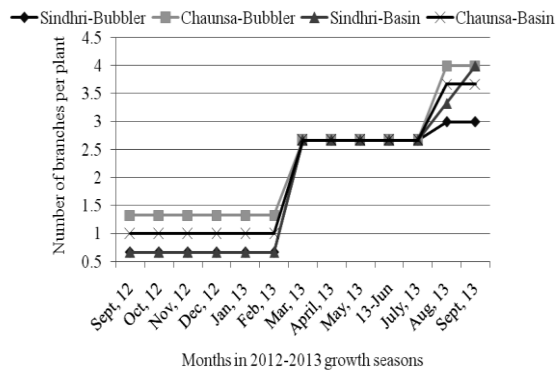

Figure 4: Increments in number of branches per plant per month

Statistical Analysis Results

The performance of bubbler and basin irrigation methods was analyzed on the basis of soil physical properties and mango plant growth parameters. Null hypothesis whether they are different from each other was tested. The results were statistically verified by using the Analysis of Variation (ANOVA) for three replications under bubbler and basin irrigation methods, and the statistical significant differences between irrigation methods were determined by F-test values at 5% probability level. The effect of irrigation methods on dry bulk density, soil porosity, infiltration rate, plant height, stem girth and number of branches were analyzed. The statistical results are presented in the Tables 4 through 5. The irrigation methods were found statistically significant as reflected by F-test values i.e. 11.55, 8.99 and 31.29 ($p<0.05$) for dry bulk density, soil porosity and infiltration rate respectively. Similarly, the impact of mango varieties and interaction (irrigation*variety) on soil hydraulic properties were non-significant at $\alpha = 0.05$. ANOVA results for plant growth parameters are shown in Table 5. The impact of irrigation methods, mango varieties and interaction (irrigation*variety) on plant height, stem girth and number of branches per plant are the non-significant at $\alpha = 0.05$.

Tukey's HSD all-pair wise comparisons test for bubbler and basin irrigation methods was performed to determine the comparison between dry bulk density, soil porosity, infiltration rate means at $\alpha = 0.05$. The ANOVA results for all-pair wise for these parameters are summarized in Table 6. As per Tukey's test the means were divided into two A and B groups. The means between the groups are significant at $\alpha = 0.05$. The Tukey's test revealed that the performance of basin irrigation method was significantly different in terms of dry bulk density, soil porosity and infiltration rate as compared to bubbler irrigation method. Moreover, the all-pair wise

Table 4. Effects of irrigation methods on soil physical properties

Source	DF	SS	MS	F	P
Dry bulk density					
Source	DF	SS	MS	F	P
Replication	2	0.00678	0.00339	1.27	0.2875
Irrigation	1	0.01309	0.0309	11.55	0.0011
Variety	1	0.00351	0.00351	1.31	0.2555
Irrigation*Variety	1	0.00697	0.00697	2.66	0.1070
Error	78	0.20437	0.00262		
Total	83	0.25251			
	Grand Mean 1.2565			CV 4.07	
Soil Porosity					
Source	DF	SS	MS	F	P
Replication	2	1.059	0.5294	0.15	0.8644
Irrigation	1	32.625	32.6253	8.99	0.0036
Variety	1	0.407	0.4074	0.11	0.7384
Irrigation*Variety	1	0.077	0.0774	0.02	0.8849
Error	78	286.487	3.6729		
Total	83	320.656			
	Grand Mean 53.191			CV 3.60	
Infiltration rate					
Source	DF	SS	MS	F	P
Replication	2	0.02000	0.01000	0.08	0.9250
Irrigation	1	3.96750	3.96750	31.29	0.0008
Variety	1	0.18750	0.18750	1.48	0.2634
Irrigation*Variety	1	0.06750	0.06750	0.49	0.5085
Error	6	0.82000	0.13667		
Total	11	5.06250			
	Grand Mean 6.6250			CV 5.58	

Note: DF is Degrees of Freedom; SS is Sum of Squares; MS is Mean Square; F is F-test value; CV the variability coefficient and p is Probability

Table 5. Effects of irrigation methods on plant growth parameters

Source	DF	SS	MS	F	P
Increased in mango plant height					
Source	DF	SS	MS	F	P
Replication	2	5.06	2.5278	0.05	0.9502
Irrigation	1	19.51	19.5069	0.39	0.5309
Variety	1	27.56	27.5625	0.56	0.4564
Irrigation*Variety	1	65.34	65.3403	1.33	0.2516
Error	138	6804.03	49.3045		
Total	143	6921.49			
	Grand Mean 4.2569			CV 164.95	
Increased in stem girth					
Source	DF	SS	MS	F	P
Replication	2	0.00014	0.00007	0.02	0.9759
Irrigation	1	0.00085	0.00085	0.30	0.5853
Variety	1	0.00293	0.00293	1.03	0.3115
Irrigation*Variety	1	0.00085	0.00085	0.30	0.5862
Error	138	0.39438	0.00286		
Total	143	0.39915			
	Grand Mean 0.0274			CV 194.89	
Increased in number of branches per plant					
Source	DF	SS	MS	F	P
Replication	2	0.1667	0.08333	0.20	0.8169
Irrigation	1	0.0625	0.06250	0.15	0.6973
Variety	1	0.0069	0.00694	0.02	0.8968
Irrigation*Variety	1	0.0625	0.06250	0.15	0.6982
Error	138	57.1389	0.41405		
Total	143	57.4375			
	Grand Mean 0.2292			CV 280.79	

Table 6. Tukey HSD all-pair wise comparison test for bubbler and basin irrigation methods

Dry bulk density		
Irrigation Method	Bubbler	Basin
Mean	1.2757	1.2374
Homogeneous Group	A	B
Standard Error for Comparison 0.0112	Critical Q Value 2.815	
Critical Value for Comparison 0.0222		
Soil porosity		
Irrigation Method	Bubbler	Basin
Mean	53.814	52.568
Homogeneous Group	A	B
Standard Error for Comparison 0.4182	Critical Q Value 2.815	
Critical Value for Comparison 0.8324		
Infiltration rate		
Irrigation Method	Bubbler	Basin
Mean	7.2000	6.0500
Homogeneous Group	A	B
Standard Error for Comparison 0.2134	Critical Q Value 3.461	
Critical Value for Comparison 0.5223		

comparison test was not performed for plant height, stem girth and number of branches per plant at desired significant level ($\alpha = 0.05$).

CONCLUSION

The soil texture did not change under bubbler and basin irrigation methods. The average dry bulk density of the soil increased while the average porosity and infiltration rate of the soil decreased due to cultivation practices as well as application of groundwater under bubbler and basin irrigation methods. Plant growth parameters were not significantly affected by irrigation methods. The distribution uniformity values under bubbler irrigation method were greater than 92%, which indicates that the bubbler irrigation method was working satisfactory according to its design. About 30.3% of water can be saved under bubbler irrigation as compared to basin irrigation method that could be utilized to irrigate the additional fallow agricultural land. The bubbler irrigation method controls the weed growth and thus, it can save some of the labor. The present study needs to be continued to observe the long term effects of bubbler and basin irrigation methods on plant growth and yield in order to advise concrete recommendations.

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