African Journal of Agricultural Research Vol. 7(10), pp. 1542-1549, 12 March, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.1178
ISSN 1991-637X ©2012 Academic Journals

Full Length Research Paper

Performance assessment of surface and subsurface drip irrigation system for date palm fruit trees

Talat Farid Ahmed[1]*, Hashim Nisar Hashmi[2], Abdul Razzaq Ghumman[2] and A. A. Sheikh[3]

[1]Farm Operation and Services, National Agricultural Research Centre, Park Road Islamabad, Pakistan.
[2]Civil Engineering Department, University of Engineering and Technology, Taxila, Pakistan.
[3]Pakistan Engineering Council, Islamabad, Pakistan.

Accepted 16 February, 2012

Surface and subsurface drip irrigation methods can play a significant role in overcoming the scarcity of water mostly in water shortage areas. A field study was conducted to know the effectiveness of surface and subsurface drip irrigation systems under different plasticity pipes, in terms of both water use requirement and yield of date palms at Al-Qassim, Saudi Arabia. Mature palm trees of different varieties with 10 m spacing for both row to row and tree to tree were selected. Three types of pipes (low, medium and high flexible that is, with wall thickness of 1.14, 0.38 and 0.41 mm, respectively) were used in both surface and subsurface drip irrigation systems. Irrigation scheduling was done through a soil moisture sensing device as well as crop water requirement guidelines for Kingdom of Saudi Arabia to ensure enough soil water levels in the soil. Considerable effects of pipe stiffness were observed on water consumption and yield for both surface and subsurface drip irrigation systems. It was found that irrigation water reduced to 36 and 56% for drip pipes of low flexibility under surface drip irrigation system while it was 49 and 53% under subsurface drip irrigation system due to better physical and hydraulic characteristic of pipe as compared to that for medium and high flexibility pipes, respectively. The yield of date palms was increased by 45 and 48% more in case of low flexibility pipe compared to that for other two types under both drip irrigation systems. Date palm response by using low flexible pipe under both surface and subsurface drip irrigation was found relatively good in respect of water consumption, yield and irrigation system itself.

Key words: Surface drip irrigation, subsurface drip irrigation, date palm, arid region, pipe flexibility.

INTRODUCTION

The continuous increase in population and the water demand by agriculture, domestic and industrial sectors have caused a great stress on world water resources. Population in emerging countries is expected to grow from 4.3 billion in 2002 to 5.5 billion in 2025 and 6.2 billion in 2050. For the least developed countries these figures will be 0.8, 1.1 and 1.6 billion, respectively (Schulz et al., 2005). Agriculture sector consumes about 70 to 72% of total water resources. Average irrigation efficiency of the world is 37% (Gittinger, 1985). World require an increase in water productivity by increasing the water use efficiency and irrigation efficiency that can be improved from present 43 to 50% by 2030 by introducing appropriate technologies and improved water management. Although surface application, the common efficiencies achieved range from 50 to 65% whereas in drip; it ranges from 97 to 98%. Its initial cost is high but it provides definitely water saving, improved yield and quality of crops (Chauhan, 2007). Increasing the efficiency of irrigation water is one of the economically viable alternatives in overcoming the water scarcity. This is not only crucial for the sustainable agricultural yield but also to meet the challenges of current environmental issues and justice, financial problems and physical barriers in the developing countries. Drip irrigation, also known as

*Corresponding author. E-mail: tafa367@yahoo.com. Tel: 92-51-8443508. Fax: 92-51-9255034.

trickle irrigation or micro irrigation is an irrigation method that minimizes the use of water and fertilizer by allowing water to drip slowly to the roots of plants, either onto the soil surface referred as surface drip irrigation system or directly onto the root zone, through a network of valves, pipe, tubing and emitters referred as subsurface drip irrigation system.

Micro irrigation system gained popularity in the recent years due to system salient features like minimized soil erosion, highly uniform distribution of water, minimized labour cost and variation in supply can be regulated by regulating the valves and drippers. Fertigation can easily be applied with minimal waste of fertilizers. Foliage remains dry thus reducing the risk of disease. System usually operated at lower pressure than other types of pressurized irrigation, resulted in reducing energy costs (Sivanappan, 1998). Ali et al. (2009) investigated the response of effluent versus fresh water on water savings, corn yields and irrigation water use efficiency by using three irrigation methods namely subsurface drip, surface drip and furrow irrigation. The irrigation scheduling was based on soil moisture and rooting depth monitoring. The highest irrigation water use efficiency was observed in subsurface drip irrigation method (2.12 kg m^{-3}) and the least was seen in furrow irrigation method (1.43 kg m^{-3}). The study results also indicated that irrigation water use efficiency was larger by irrigation with effluent compared to fresh water but difference was not statistically important. Dogan et al. (2009) studied the effect of subsurface and surface drip irrigation systems on muskmelon under semi arid climatic conditions in six different irrigation treatments (0, 25, 50, 75, 100 and 125%) of class A pan evaporation rates applied. The study results showed that highest muskmelon yields were obtained at 83 and 92% of class A pan from subsurface and surface drip irrigation systems. They showed that bigger fruits were got with optimal irrigation amounts under both irrigation systems. But there was no clear indication of irrigation water amounts on total soluble solid and flesh thickness of muskmelon fruits.

Al-Amoud et al. (2000) investigated the response of date palm trees under different water regimes (50, 100 and 150% of pan evaporation rate) using three irrigation methods like basin, bubbler and trickle irrigation. The maximum yield was produced from palm trees irrigated with the trickle irrigation system followed by the basin method. The water use efficiency was the maximum for trickle irrigated plots followed by the basin plots. Al-Lawati et al. (1998) investigated the management of irrigation water on date palms plots. The soil-water balance method was used to estimate the temporal distribution of the crop coefficient under modern and traditional irrigation systems. The process was accomplished using TDR (time domain reflectometry) measurements of soil-water content, a computerized irrigation scheduling package and meteorological data from an automated weather station at the site. This study produced important baseline information on the crop water requirements of date palms under modern and traditional irrigation systems. Selim et al. (2009) found that subsurface drip irrigation system was more efficient than surface drip irrigation system on improving potato tubers yield quantity, quality parameters and nutrients concentration content. In addition to soil fertility after harvesting, Vories et al. (2009) performed an experimental investigation on corn crop under subsurface drip irrigation by comparing three irrigation levels with irrigation replacing of 100 and 60% of estimated daily water use and no irrigations. The results suggested that replacing 60% of the estimated daily evapotranspiration with subsurface drip irrigation is sufficient for maximum corn yields but more work would be needed prior to recommend the adoption of this irrigation method under corn production for farmers.

The research in this paper was undertaken with the following specific objectives:

i) Evaluation of surface and subsurface drip irrigation system in fruit trees under water scarce situations areas;
ii) Evaluation of varying flexibility drip pipes performance under both irrigation systems;
iii) Efficiency of both irrigation systems in relation to water used, yield and yield to water ratio;
iv) Economic viability of drip irrigation systems under different cropping schemes.

MATERIALS AND METHODS

Site description

The experimental site was situated in the deserts of Al-Qassim (Buraidah), Saudi Arabia. Buraidah has a typical desert climate with hot summers, cold winters and low humidity. The climate is moderately hot and dry. The average monthly highest temperature varies from minimum 30°C (December and January) to maximum 48°C (July and August). Relative humidity is about 34.6%, wind speed is 175 km/d and annual evapotranspiration is 2489 mm. The experimental area was 2.1 ha, having 170 matured date palm trees. The row to row and tree to tree distances were approximately 10 m. The study area consists of sandy loams with traces of gravel.

Experimental design

The experimental site used for this investigation under surface and subsurface was the same. Only difference was different flexibility drip pipes buried beneath the soil at recommended depth under subsurface drip irrigation system while these pipes were on the ground surface under surface drip irrigation system. The site was divided into five sub-areas, each having four rows of trees. In order to investigate the effect of pipe flexibility on the experimental parameters, drip pipes of different brands were used in the subsurface irrigation system. The drip pipes had varying wall thickness, that is,1.14, 0.38 and 0.41 mm and consist of continuously self-cleaning pressure compensating emitters welded to the inside walls of the pipes. The discharge rates and pressure range of these pipes were 3.4, 3.5, 3.5 (l/h/m) and 28 to 104, 70 to 386 and 50 to 450 (kPa) respectively. In both drip irrigation methods, drip pipes of varying wall thickness 1.14, 0.38 and 0.41 mm was used and referred as low, medium and high flexibility. Considering the flexibility of drip pipes installed, the sub-areas were designated as low flexible drip pipe (LFDP), medium flexible drip pipe (MFDP) and high flexible

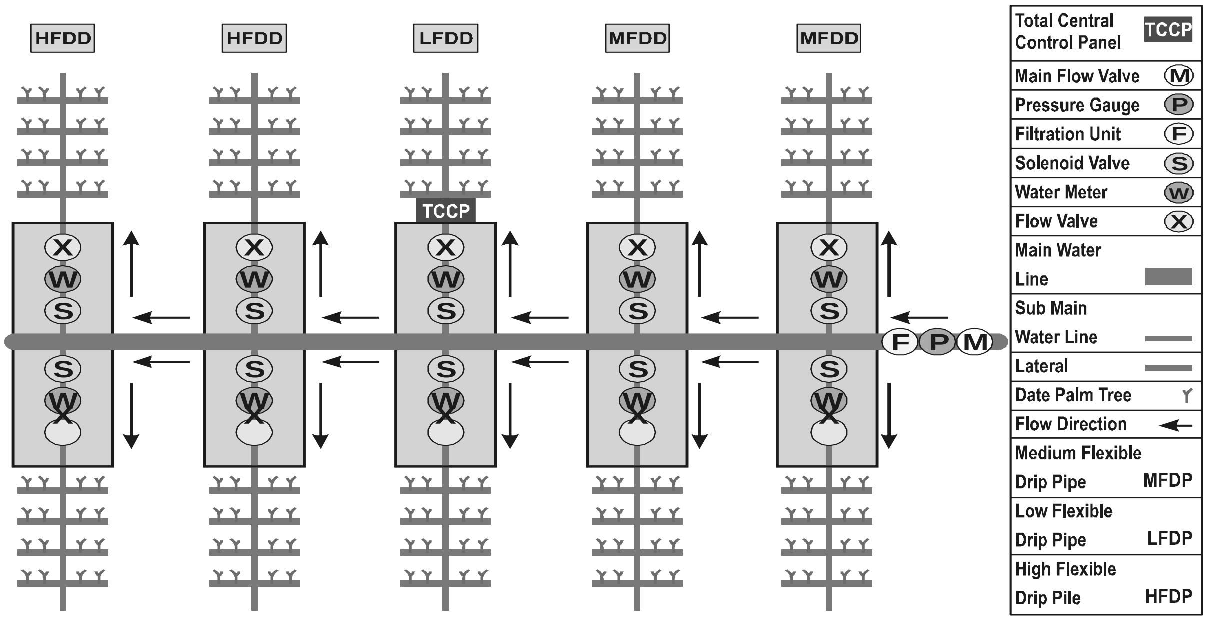

Figure 1. Layout plan of experimental site.

drip pipe (HFDP) areas. The medium flexible drip pipe area was divided into two sub areas as MFDP-1 and MFDP-2. Similarly, high flexible drip pipe area was divided into two sub areas as HFDP-1 and HFDP-2 as shown in Figure 1. Trenches were excavated mechanically and dressed manually. The drip pipes were installed at 40 cm depth from ground surface as per manufacturer recommendations under subsurface drip irrigation (Marais, 2009). The system was checked for leakage prior to back-filling.

At the inlet of water supply line, a main flow control valve, a pressure gauge and a filtration unit were fitted. The main line was connected to sub-main which leads water to sub-areas through laterals. These laterals were placed above ground surface in surface drip irrigation method study, while these were buried in subsurface drip irrigation method study. Each sub-area was divided into two wings fitted with a separate set of valves. The set includes a solenoid valve, a water meter and a flow control valve. The irrigation of all sub-areas was scheduled and controlled by a unit called 'total central control panel' (that is TORO custom command) as shown in Figure 2.

Irrigation scheduling and system operation

Irrigation scheduling consists of applying the right amount of water at the right time. Its purpose is to maximize irrigation efficiency by applying the appropriate amount of water needed to replenish the soil moisture to the desired level. Water and soil sampling of the experimental site was carried out as shown in Table 1. The testing was done and analysis revealed that the soil had low permeability and alkalinity. The texture of soil was sandy clay loam with traces of gravel. The perennial net surface water requirement under this region is 17235 m^3/ha (100 trees per hectare). The analysis was carried out from January up to August which is the harvest time of the dates in this region. Monthly irrigation schedule was prepared as per guidelines suggested for the region (Al-Zeid, 1988). Uniform amount of water was applied. Figures 3 and 4 depict the applied quantity of irrigation water in surface and subsurface irrigation method, respectively. Soil moisture sensing device that can measure moisture at a depth of 0.8 m or lower was used to know the soil moisture status before and after irrigation application.

Soil moisture sensing device scale ranges from 0 to 10°, 0 indicates a fully dry condition, 2 to 4 represents average dry state, 4 to 6 average state, 6 to 8 average wet state and 10 shows fully wet condition. The corresponding readings of the moisture meter were recorded.

RESULTS AND DISCUSSION

Irrigation water was applied to all sub-areas as per irrigation scheduling (Figures 3 and 4). It can be seen in Figure 5 that the quantity of water applied for low flexible drip pipe is the least of all three types either used in surface or subsurface drip irrigation. Although, the irrigation schedule was same for all blocks but discharge rates were varying in low, medium and high flexible pipes due to different discharges of their emitters. Under surface drip irrigation system, for the same period, in the low flexible drip pipe type, the total quantity of water used was 328 m^3 as compared to 514 and 744 m^3 for medium and high flexible drip pipe types, respectively. While under subsurface drip irrigation system, it was 229 m^3 as compared to 451 and 485 m^3 for medium and high flexible drip pipe types, respectively. The maximum water use efficiency was observed in low flexible pipes because there was no opening of joints resulting in no leakage of water and non-blockage of built-in emitters. This quantity is 36 and 56% lower than that used in medium and high flexible pipe types, respectively for surface drip irrigation system. The quantity of water used under low flexible pipe type for the peak period, that is, for July and August

Figure 2. Total central control panel.

was also determined. It was found to be 47 L per tree per day under surface drip irrigation system while under subsurface drip irrigation system; it is 49 and 53% lower than that used in medium and high flexible pipe types respectively. The quantity of water used under low flexible pipe type for the peak period, that is, for July and August was also determined. It was found to be 35 L per tree per day under subsurface drip irrigation system.

The drip pipes were installed 40 cm (as advised by the manufacturer) from ground surface having overloaded soil which was further compacted due to mechanical operation on the experimental field under subsurface drip irrigation system while these drip pipes were placed above the ground surface under surface drip irrigation system. This resulted in constriction of the high flexible pipes which were less stiff. This obstructed water flow which in turn affected the performance of emitters. The increased water pressure in the pipes produced leakage or even opening of the joints. These trickling joints caused water losses. This problem was found less prominent in the medium flexible pipes and the least in the low flexible pipes. The joints and emitters in the low flexible pipes worked well so no extra maintenance for this type was required throughout the study period both surface and subsurface drip irrigation system. It can be concluded that the high flexible pipe type is less efficient under subsurface irrigation system and also for surface drip irrigation system due to its high flexibility. Similarly, yield and yield to water ratio trend for all the pipe types under both surface and subsurface drip irrigation system can be seen in Figures 6 and 7, respectively. Under surface drip irrigation system, the yield of the dates per tree for the area under the low flexible pipe type was found to be 126 kg/tree whereas the yield for the areas under the medium and high flexible pipe types was 71 and 61 kg per tree respectively. Thus the trees under low flexible pipe type produced 44 and 52% more yield than those under medium and high flexible pipe types respectively. While under subsurface drip irrigation system, the yield of the dates per tree for the area under the low flexible pipe type was found to be 115 kg/tree whereas the yield for the areas under the medium and high flexible pipe types was 70 and 58 kg/tree respectively. Thus, the trees under low flexible pipe type produced 39 and 50% more yield than those under medium and high flexible pipe types respectively. It is because the low flexible pipe type is more efficient hydraulically.

Actually, in this pipe system, the water flow is smooth and continuous as it being trouble free from joints leakage and can better sustain the load of overburden soil. The comparison of the date production under surface and subsurface drip irrigation system is shown in Figure 6. The results shows that under surface drip irrigation system, the water use efficiency for low flexible pipes has been 17, 7 and 6 kg/m^3 in case of medium and high flexible pipes, respectively. Quantitative analysis shows that the water use efficiency in low flexible pipe type is 59 and 65% more than that under the medium and high flexible pipe types respectively. While under subsurface drip irrigation results has been calculated as 22, 10 and 7 kg/m^3 in case of medium and high flexible pipes respectively. Quantitative analysis shows that the dates

Table 1. Water and soil analyses of study area.

Water analysis	
Characteristic	**Value**
Water pH	7.36
EC (dS/m)	1.89
Total dissolve salts (TDS) (mg/L)	949
Alkalinity (mg/L)	140
Chlorides (mg/L)	319
Hardness (mg/L)	136
Ca^{2+} (mg/L)	44
Mg^{2+} (mg/L)	6.26
Fe^{2+} (mg/L)	0.026
SO_4^{2-} (mg/L)	354
NO_3^- (mg/L)	34
Soil analysis	
Physical characteristic	**Value**
Sand (%)	65
Loam (%)	15
Caly (%)	20
Texture	Sandy clay loam
Field capacity (%)	11.2
Wilting point (%)	5.7
Available moisture (%)	5.5
Apparent density (g/cm^3)	1.62
Chemical characteristic	**Value**
Soil pH	7.8
Electrical conductivity EC (dS/m)	2.57
Positive ions (cations) (meq/L)	
Ca^{2+}	21.3
Mg^{2+}	9.3
Na^+	8.4
Negative ions (Anions) (meq/L)	
CO_3^{2-}	0.22
HCO_3^-	2.3
Cl^-	11
Organic matter (%)	0.084
Available elements (ppm)	
P	6.56
K	152

water use efficiency in low flexible pipe type is 55 and 68% more than that under the medium and high flexible pipe types respectively. It can be seen in Figure 7 under both drip irrigation system. The cost analysis viable showed that subsurface drip irrigation system was more economically.

Conclusions

This study examined the performance of a surface and subsurface irrigation system using pipes of varying flexibility. Based on the experimental results, it has been concluded that low flexible drip pipe performed well under

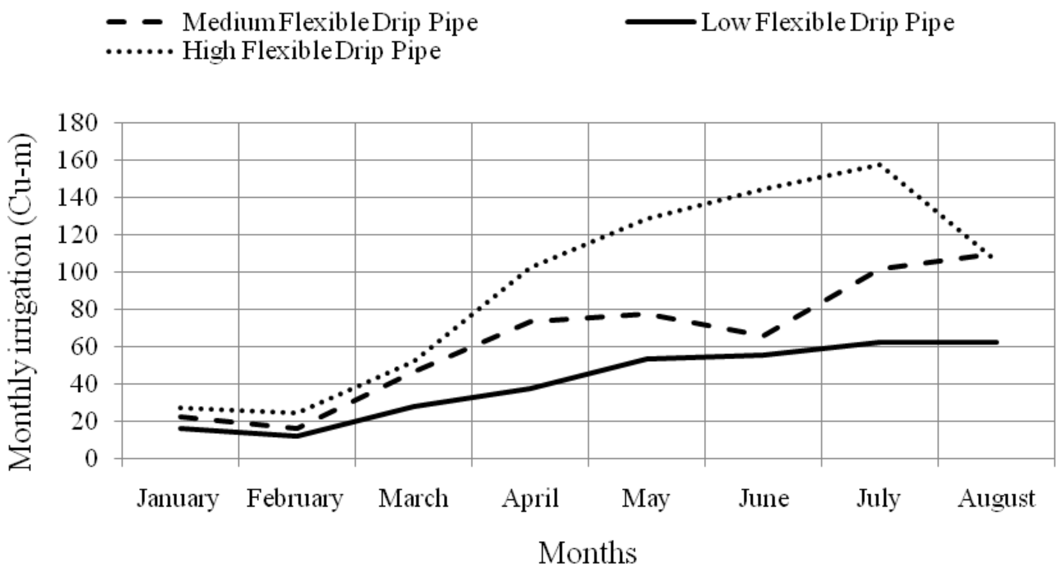

Figure 3. Monthly irrigation application to date palm using low, medium and high flexible drip pipes under surface drip irrigation system.

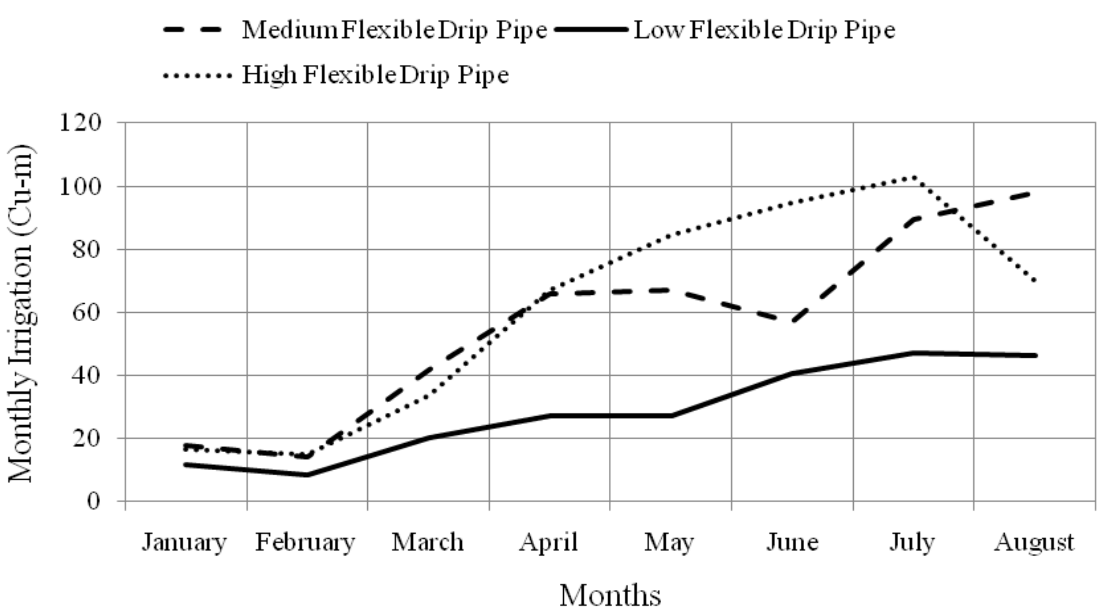

Figure 4. Monthly irrigation application to date palm using low, medium and high flexible drip pipes under subsurface drip irrigation system.

subsurface drip irrigation system due to its better physical and hydraulic characteristics as compared to other medium and high flexible pipes used. In addition to that low flexible pipes were equally efficient and better for surface drip irrigation than other medium and high flexible pipes. Total quantity of water used in subsurface drip irrigation system was less as compared to surface drip irrigation system under varying flexible drip pipes types used due to efficient consumption of all water applied. Low flexible drip pipe consumed least water in peak period that is for July and August due to its efficient working performance under subsurface. Under sub-surface drip irrigation system, the yield of the fruit per tree for the area having low flexible pipe type was more as compared to surface drip irrigation system containing low flexible pipe due to better physical and hydraulic properties of pipe, non evaporation and wind effects of drip irrigation system. The water use efficiency for low

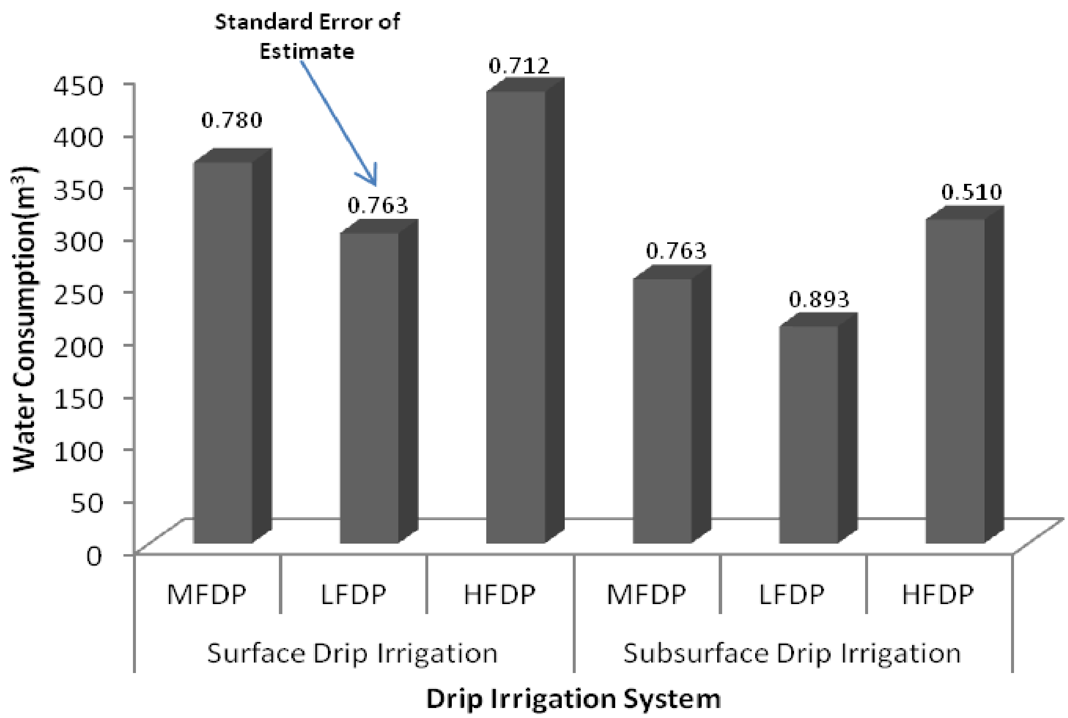

Figure 5. A comparison of water consumption (m^3) of date palm for three drip pipe types under surface and subsurface drip irrigation system.

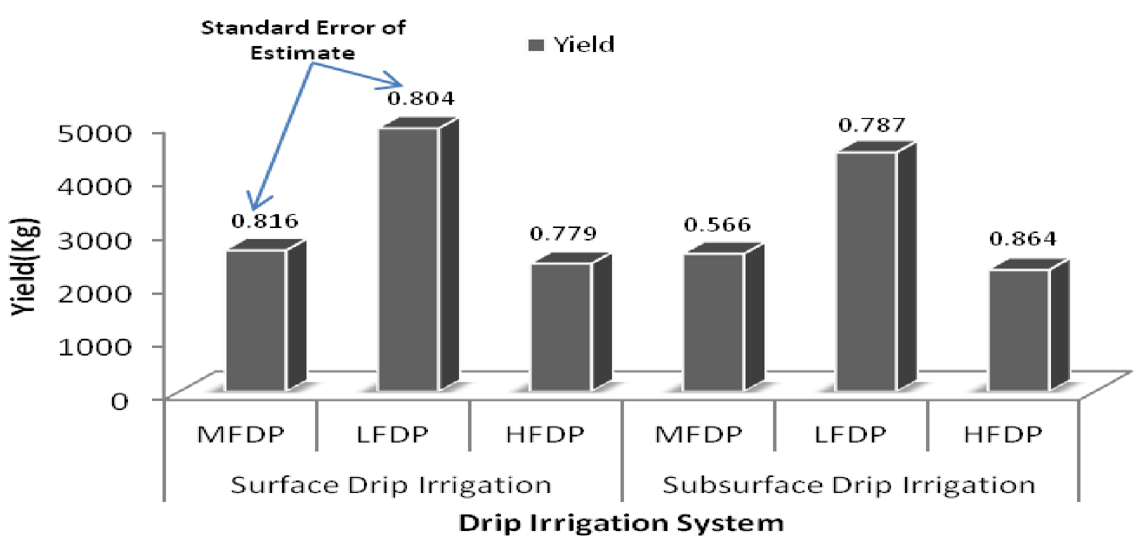

Figure 6. A comparison of date production for three drip pipe types under surface and subsurface drip irrigation system.

flexible drip pipes under subsurface drip irrigation system was more than surface drip irrigation due to bigger wetted volume of soil in root zone and climatic factors. Subsurface drip irrigation system eliminates the weed growth around the tree and prevents salt accumulation on the soil surface which was not in the case of surface drip irrigation system. Subsurface irrigation facilitated the ease of mechanical field operation for fruit orchard as all pipes were underground at recommended depth. Fixed and capital costs of subsurface drip irrigation system was more but outcomes in the shape of revenue and gross margin in US$/ha/season under subsurface drip irrigation

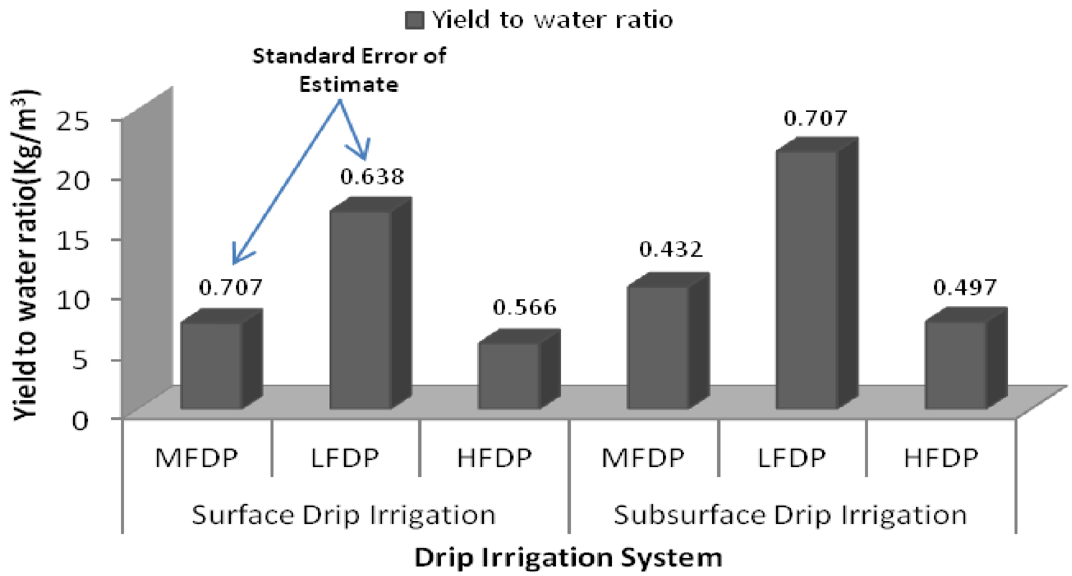

Figure 7. Comparison of dates production per tree per m^3 of water consumption using three drip pipe types under surface and subsurface drip irrigation system.

system was more as compared with surface drip irrigation system.

Further investigation of subsurface drip irrigation by using low flexible pipe (self compensating dripper pipe type) needs to be undertaken for other fruit trees to confirm the benefits of the use of low flexible drip pipes under this irrigation system. For efficient system working maintenance schedule as per recommended by the company must be followed to get optimum results under fruit trees.

ACKNOWLEDGEMENTS

The staffs of Al-Watania Agriculture Company and its Director General Dr Khalid Al-Maulahey are highly acknowledged for their coordination and cooperation in setting-up experimental facility and collection of data. The cooperation and guidance of Dr. Ahmad Al-amoud, Consultant to Al-Watania Agriculture Company is also appreciated and acknowledged.

Notations: ETo, evapotranspiration; **LFDP,** low flexible drip pipe; **MFDP,** medium flexible drip pipe; **HFDP,** high flexible drip pipe; **RFT,** running foot.

REFERENCES

Al-Amoud AI, Bacha MA, Al-Darby AM (2000). “Seasonal Water Use of Date Palms in the Central Region of Saudi Arabia”. Int. J. Agric. Engine., Saudi Arabia, 9(2): 51-62.

Al-Lawati EAM, McCann IR, Shayya WH (1998). “Date Palm Water Requirements in the Interior Region of the Sultanate of Oman”. ASAE Annual International Meeting, Orlando, Florida, USA, Paper no. 982(185):13-20.

Al-Zeid AA (1988). “Guide for Crop Irrigation Requirements in the Kingdom of Saudi Arabia”. Ministry of Agriculture and Water, Department of Agricultural Development, Saudi Arabia, pp. 54-73.

Chauhan SH (2007). Elements of micro irrigation and its crop application. Published by International Book Distributing Co, Lucknow, India.

Dogan E, Kirnak H, Berekatoglu K, Bilgel L, Surucu A (2009). “Water stress imposed on muskmelon (*Cucumis Melo* L.) with subsurface and surface drip irrigation systems under semi-arid climatic conditions”. Irrigation Sci., 26(2): 131-138.

Gittinger JP (1985). “Economic analysis of agricultural projects. The John Hopkins Press Baltimore and London, pp. 29-37.

Marais A (2009). “Subsurface drip irrigation systems, Netafim S.A. P.O. Box 3240 White River 1240 RSA.

Schulz B, Thate CD, Labhestwar VK (2005). “Irrigation and Drainage main contributors to global food production”. Irrigation and Drainage 54: 263-278.

Selim EM, Mosa AA, El-Ghamry AM (2009). “Evaluation of humic substances fertigation through surface and subsurface drip irrigation systems on potato grown under Egyptian sandy soil conditions”. Agric. Water Manage., 96(8):1218-1222.

Sivanappan RK (1998). ”Low cost micro irrigation system for all crops and all farmers” In: Proceedings of Workshop Micro irrigation and Sprinkler irrigation systems April 1998 at New Delhi. Organized by Central Board of Irrigation and Power, Edited by CVJ Verma, pp. IV-15-IV-20.

Vories ED, Tacker PL, Lancaster SW, Glover RE (2009). “Subsurface drip irrigation of corn in the United States Mid-South”. Agriculture, 96(6): 912-916.