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Effect of Irrigation Systems and Irrigation Water Regime on the Vegetative Growth of Date Palm (*Phoenix dactylifera)* Plantation under Khartoum State Conditions, Sudan

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Article history: Received: 28th December 2015
Accepted: 18th May 2016

Abstract

The experimental work was carried out at Nobles Farm for Modern Systems located at 25km south east of Khartoum during two consecutive years 2011/012 and 2012/013 with the objectives of determining the optimum water requirements of the young date palm tree and investigating the response of young date palm of Barhi cultivar to different water regimes. The treatments included drip irrigation and conventional basin irrigation systems with three irrigation water regimes (50%, 75% and 100% ETc). Split plot experimental design with three replications was used in which the two irrigation systems were assigned to the main plots while irrigation water regimes were allocated to the sub plots. The variations among the means were checked by the Least Significant Difference (LSD). A computer program (SAS statistical package) was used to analyze the data. Crop water requirement was determined using CROPWAT version 8 computer model. The parameters tested were; plant height (cm), number of leaves per plant, number of leaflets per leaf, stem diameter (cm), number of offshoots and length of offshoots (cm).The optimum crop water requirement of young date palm tree was found to be 20 m^3 / tree/year for drip irrigation, while it was 39 m^3/ tree/year under the conventional basin irrigation.Drip irrigation gave the highest mean values of vegetative growthas compared to conventional basin irrigation system. The irrigation water amount of 100% ETc significantly (P = 0.5) increased the vegetative characteristics as compared to 50% ETc. The vegetative growth was significantly affected by the interaction between the irrigation systems and the different irrigation water regimes used. The reduction percentage in vegetative growth with reduced water 75% ETc was found to be 20% of the value of full crop water requirement (100% ETc), while it was increased to reach 43% of the value of full crop water requirement under 50% ETc. It is to be concluded that, drip irrigation system with 100 ETc% are highly needed to increase the vegetative growth of date palm offshoots.

Keywords: Irrigation systems; deficit irrigation; irrigation water regimes; Date palm offshoots

Introduction

A great challenge for the agricultural sector is to produce more food under water scarcity conditions particularly in arid and semi-arid regions (Ali *et al.*, 2009). Under these limitations in water availability, it is required todevelop new irrigation scheduling approaches focused on ensuring optimal use of available water with high efficiency, and not based onfull crop water requirements. The determination of theseefficient and effective irrigation schedules (including deficitirrigation strategies) require the accurate determination ofwater requirements for the main crops, in order to assist the farmers in deciding when and how much to apply to theircrops. If water can be applied efficiently in an irrigated field, water is saved and both crop quantity and quality are increased.

Like any other fruit tree, date palm requires sufficiency in water of acceptable quality to reach its potential yield. Different irrigation techniques are available to irrigate crops, but not all of them are suitable for irrigation of date palm. The drip irrigation is one of the most efficient irrigation systems that are used to irrigate date palm. It can play a significant role in overcoming the scarcity of water mostly in water shortage areas by uniformly distributing water in agricultural fields and it has advantages over conventional surface irrigation as an efficient means of applying water, especially where water is limited (Camp, 1998).According to Hassan (2001) date palm tree has the ability to maintain its consumptive use under certain conditions and has developed a rootsystem capable to search for moisture to deepest soil profile. Ali (2013) studied the stability and vegetative growth of date palm in the different irrigation treatments (100%, 80% and 60% of Class A pan). The results demonstrated that, there were significant effects on stability and vegetative growth of date palm. On the other hand, AI-Amoud *et al.* (2000) conducted a field experiment to investigate the response of date palm trees, of Seleg cultivar, to different water regimes (50, 100 and 150% of pan evaporation rate), using three irrigation methods: basin, bubbler and trickle irrigation systems. The results revealed that, yield increased as irrigation quantity increased and the maximum yield was produced from palm trees irrigated with trickle irrigation system followed by the basin method; while Ibrahim *et al.* (2012) reported that, the interaction of irrigation systems and amount of watering significantly affected the growth parameters. Al-Ghobari (2007) showed that, the average of date palm irrigation water consumption under surface, bubbler and drip irrigation systems was 19700, 14200 and 6700 m^3/ha/year, respectively. Mohebi (2005) studied the effect of water use in drip irrigation and surface irrigation methods on yield and vegetative characteristics on date palm. He found that there were significant effect on leaflet number, shade perimeter and trunk perimeter. Therefore the objectives of this study were to determine the optimum water requirements of the young date palm tree and investigating the response of young date palm of Barhi cultivar to different water regimes.

Materials and Methods

The experimental work was carried out at Nobles Farm for Modern Systems located 25km south east of Khartoum (longitude 32^o 42' E, latitude 15^o 29' N and altitude 377 m amsl) during two consecutive years 2011/012 and 2012/013 in a sandy loam soil. The climate is semi-arid with low relative humidity and daily mean maximum and minimum temperatures of 35.4^{0}C and 21.2^0 C, respectively. The annual rainfall is limited and usually occurs in the form of short intense thunder storms. Hence, the mean annual rainfall value was about 15.2mm occurring mainly in July and August. This means that water is deficient and crop production must be based on irrigated farming systems according to the requirements of the adopted crops.

Description of irrigation systems

1. Drip irrigation system: after the land was ploughed, harrowed and leveled, a drip irrigation system was designed to irrigate date palm- Barhi cultivar with the following components.

a. ***Control unit:*** to control discharge and pressure in the entire system, two valves were fixed; one before the pumping unit and the other after it, as well as twenty sevenvalves which were used at the beginning of the laterals. A pressure gauge was used to measure the pressure in the system.

b. ***The main lines:*** the main pipe line was made of polyvinyl chloride (PVC) and the length was 200 m long and 7.62 cm (3″) in diameter.

c. ***Sub-main lines:*** three sub main pipe lines were made of polyvinyl chloride (PVC) were installed, 65m long and 5.08 cm (2″) in diameter.

d. ***The lateral lines:*** the lateral pipes were made of black liner low density polyethylene (LLDPE). Nine laterals per sub main were made, each 24 m long and 2.54 cm (1″) in diameter joined to the sub-main at 7 m spacing between laterals.

e. ***Emitters:*** point source emitter's type of 4 L/h rated discharge were used in this system. Four emitters were fixed for each date palm tree.

2. ***Basin irrigation system:*** circular basins (2.3 m in diameter) were constructed around the base of each tree stem. Earthen bunds or barriers made around the basin in order to hold the applied irrigation water.

In this study drip irrigation and conventional basin irrigation systems with three irrigation water regimes (50%, 75% and 100% ETc) were used. The experiment was arranged in split plot design with three replications. The young date palms cv. Barhi (*Phoenix dactylifera)* of age of one year old obtained from tissue culture were planted in April2011 after seed bed preparation with 7m*7 m spacing.Treatment combinations were as follows:

1. Drip irrigation system and water use based on 100% ETc.
2. Drip irrigation system and water use based on 75% ETc.
3. Drip irrigation system and water use based on 50% ETc.
4. Basin irrigation system and water use based on 100% ETc.
5. Basin irrigation system and water use based on 75% ETc.
6. Basin irrigation system and water use based on 50% ETc.

The daily water use (L/day) by date palm tree was calculated by the relation mentioned by Esmail (2002) as follows:

$$\text{The daily water use (L/day)} = \frac{ETc*A}{Ea} \quad \ldots\ldots\ldots (1)$$

ETc = Crop water requirement (mm/day).
A = Area specified for each tree m^2.
Ea = Irrigation application efficiency.

Estimation of date palm water requirement (ETc) is derived from crop evapotranspiration (crop water use) which is the product of the reference evapotranspiration (ETo) and the crop coefficient (Kc). The reference evapotranspiration was estimated based on the FAO Penman-Monteith equation, using climatic data (Hanson and May, 2004) as follows:

$$ETc = ETo*Kc*Ks*Kr \ldots\ldots\ldots (2)$$

Where:
ETc = Crop evapotranspiraion (mm/day).
ETo = Reference evapotranspiration (mm/day).
Kc = Crop Coefficient (dimensionless).
Ks = Soil water availability factor = 0.9 due to the soil type (sandy loam).
Kr = A reduction factor.

A reduction factor (Kr) was calculated from the ground cover value (GC). It is defined as the fraction of the total surface area actually covered by the foliage of the trees when viewed directly from above. In order to calculate GC, the diameter of shaded area in centimeters (cm) was taken after mid-day. The ground cover, as percentage was calculated by the procedure described by Hellman (2004) as follows:

Area per tree = Row width ×Tree spacing within row
Shaded area per tree = Tree spacing within row × D

$$GC\ (\%) = \frac{\text{Shaded area per tree}}{\text{Area per tree}} \times 100 \ldots(3)$$

Where:
D = Average width of measured shaded area between two trees.
GC = Ground cover (%).

The reduction factor (Kr) was estimated using equation (4) as suggested by Esmail (2002):

$$Kr = 0.1GC^{0.5} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Measurement of rainfall: daily rainfall is measured using the standard ordinary rain gauge exposed 1 m above level ground away from buildings and trees. The diameter of the standard gauge is 5 inches (12.7 cm). There is a measuring Jar calibrated to read the rainfall in mm this Jar should only be used with 5in diameter rain gage. A recording rain gauge is used to give a continuous record of rainfall to type of rain gauges is very important because it gives the intensity of rainfall (Adam, 2014).

Effective rainfall: effective rainfall is defined as the fraction of rainfall that is effectively intercepted by the vegetation or stored in root zone and used by the plant – soil system for evapotranspiration. It can be estimated by the following equation mentioned by Adam (2014):

$$P_{ef} = E.\ P_{tot} + A$$

Where:
P_{ef} = Effective rainfall over the growing season.
E = Ratio of consumptive use of water (cubic) to $P_{tot.65}$.
P_{tot} = Total rainfall over the growing season.
A = Average irrigation application.

The vegetative growth parameters tested included; (plant height (cm), number of leaves per plant, number of leaflets per leaf, stem diameter (cm), number of offshoots and length of offshoots (cm).

Results and Discussion

The amount of water applied for young date palm tree was found to be 20 m^3/ tree/year under drip irrigation system, while it can increase to reach 39 m^3/ tree/year under conventional basin irrigation system (Figure 1). The result is in agreement with that obtained by Al-Ghobari (2007) who revealed that, the average of date palm irrigation water consumption under surface, bubbler and drip irrigation systems was 19700, 14200 and 6700 m^3/ha/year, respectively. On the other hand, Amiri *et al*. (2007) studied the response of date palm (cultivar Zandi) growth under three different irrigation systems: basin, bubbler and sprinkler irrigation systems. Their results demonstrated that the mean values of leaf number, leaf size, tree height and leaf mineral content of date palm were significantly influenced by irrigation systems, and the general trend of growth increased as water availability to tree increased.

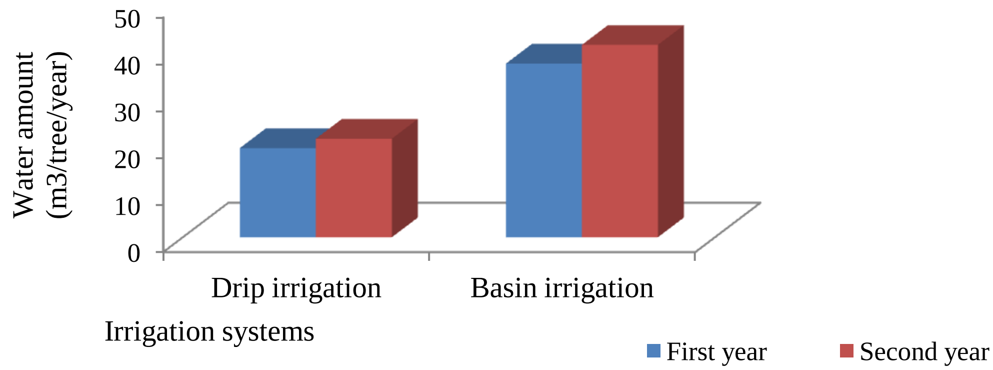

Figure 1: Effect of water quantity on the vegetative growth of young date palm

Vegetative growth of date palm offshoots cv. Barhi were significantly (P = 0.05) affected by the two irrigation systems (Table 1 and Figure 2). The drip irrigation system recorded the highest mean values of vegetative growth, while basin irrigation system ranked the least. This may be due to the fact that, drip irrigation system provided the crop with adequate water requirement at the root zone due to their high performance and efficiency. The result agrees with the result obtained by Ali (2013).

Table 1: Effect of irrigation systems on vegetative growth of young date palm

Irrigation system	Plant height (Cm)	No. of leaves	No. of leaflets/leaf	No. of offshoots/plant	Length of offshoots (cm)
Drip	138.33[a]	28.50 [a]	52.40 [a]	2.86 [a]	54.22 [a]
Basin	110.2[b]	20.50 [b]	48.7 [b]	2.00 [b]	44.50 [b]
LSD	10.55	5.60	7.17	0.59	8.43

Means followed by the same letter (s) in the same column are not significantly different at P = 0.05.

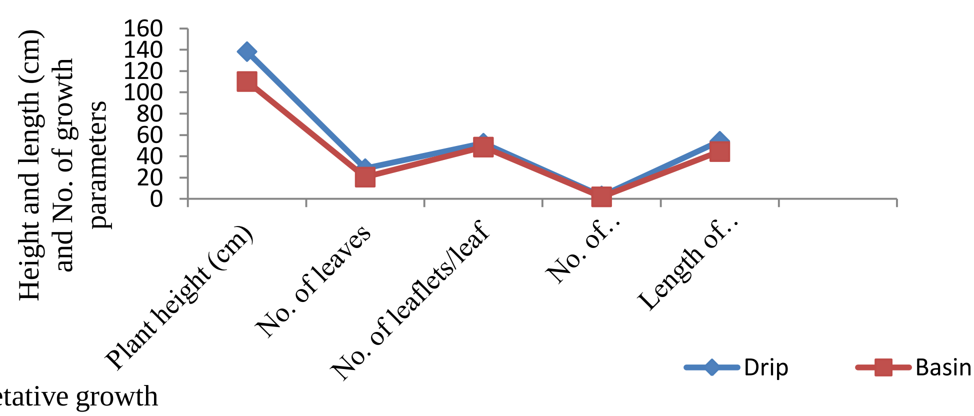

Figure 2: Effect of irrigation systems on the vegetative growth of young date palm

As presented in Table (2) and Figure (3), different water regimes significantly affected the vegetative growth of date palm offshoots. The application of 100% ETc significantly (P = 0.05) increased plant height, number of leaves, number of leaflets per leaf and stem diameter while 75% ETc in number of offshoots and length of offshoots. The reduction percentage in vegetative growth with reduced water (75% ETc) was found to be 20% of the value of full crop water requirement (100% ETc) while it was increased to reach 57% of the value of full crop water requirement (100% ETc) under (50% ETc).The result was in conformity with the result obtained by AI-Amoud *et al.* (2000) and supported by those obtained by Ibrahim *et al.* (2012).

The interaction between two systems and different water regimes significantly increased the vegetative growth of date palm offshoots. The results agreed with Mohebi (2005) and in line with those obtained by Mazahrih, *et al.* (2012).

Table 2: Effect of irrigation water regimes on vegetative growth of young date palm

Water regimes	Plant height (Cm)	No. of leaves	No. of leaflets/leaf	No. of offshoots/plant	Length of offshoots (cm)
100%	140.50[a]	29.00[a]	53.10[a]	2.30[a]	52.13[a]
75%	112.5[b]	21.50[b]	49.80[b]	2.00[a]	43.00[b]
50%	80.70[c]	17.20[b]	47.00[b]	1.30[b]	25.40[c]
LSD	12.52	5.34	4.90	0.50	10.38

Means followed by the same letter (s) in the same column are not significantly different at P = 0.05

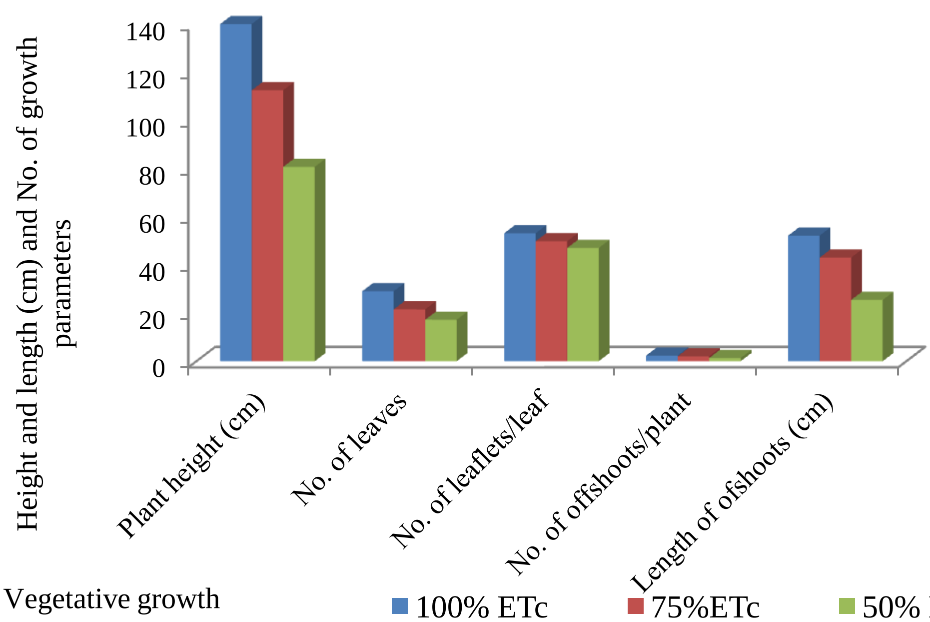

Figure 3: Effect of irrigation water regimes on the vegetative growth of young date palm

Conclusion

The response of young date palm (cultivar Barhi) growth under two irrigation systems (drip and basin irrigation systems) was significantly affected by the three irrigation water regimes (100%, 75% and 50% ETc). Drip irrigation system with 100% ETc gave the best results in the vegetative growth parameters. The reduction percentage in vegetative growth parameters with reduced water 75% ETc was found to be 20% of the value of full crop water requirement (100% ETc)while it was increased to reach 43% of the value of full crop water requirement (100% ETc) under 50% ETc. The general trend of growth increased as water availability to tree increased.

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تأثير نظم الري وكميات الري علي خصائص نمو نخيل التمر تحت ظروف ولاية الخرطوم _ السودان

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المستخلص:

أجريت تجربة بمزرعة شركة نوبلز للأنظمة الحديثة التي تقع 25 كلم جنوب شرق الخرطوم لعامين متتالين (2011 و 2012) بغرض تحديد الإحتياجات المائية المناسبة لأشجارنخيل التمرودراسة إستجابة أشجار نخيل التمر صنف برحي لمختلف كميات الماء (50% و 75% و 100% كنسبة من بخرنتح المحصول). إشتملت المعاملات على نظام الري بالتنقيط و نظام الري بالأحواض التقليدي مع كميات مختلفة من الماء (50% و75% و100% كنسبة من بخرنتح المحصول). نفذت التجربة بتصميم القطع المنشقة بثلاثة مكررات و خصصت معاملات نظم الري للقطع الرئيسية و معاملات كميات الماء للقطع المنشقة. حللت البيانات بإستخدام برنامج الحاسوب ساس (SAS) وأستخدمت أقل فرق معنوي (LSD) لمقارنة المتوسطات.تضمنت القياسات التي درست الخصائص الهايدروليكية لنظام الري بالتنقيط مثل كفاءة الإضافة و معامل التوزيع و تجانس التوزيع كما جمعت بيانات عن صفات النبات: إرتفاع النبات وعدد الأوراق وعدد الوريقات في كل ورقة ومحيط الساق وعدد الفسائل لكل شجرة و طول الفسيلة. أوضحت النتائج أن الإحتياجات المائية ألأمثل لنخيل التمر الصغيرة كانت 20م^3 / شجرة /سنة عند إستخدام نظام الري بالتنقيط بينما زادت النسبة لتصل 39م^3 / شجرة/سنة تحت نظام الري بالأحواض التقليدي. أعطى نظام الري بالتنقيط أعلا قيم في خصائص نمو نخيل التمر عند مقارنته بنظام الري بالاحواض التقليدي. إضافة نسبة 100% بخرنتح معنويا زادت متوسط قيم لطول الشجرة و عدد الاوراق لكل شجرة و عدد الوريقات للورقة الواحدة ومحيط الساق و عدد الفسائل للشجرة الواحدة وطول الفسيلة الواحدة عند مقارنتها بنسبة 50% بخرنتح. أعطى التفاعل بين نظم الري وكميات الري المختلفة إختلافات معنوية في قياسات نمو الأشجار. وجد ان نسبة الإنخفاض في خصائص النمؤ نتيجة لأثر الري الناقص 75% هي 20% من قيمة أقصى إحتياج مائي (100% من البخر نتح) بينما زادت هذه النسبة لتصل 43% من قيمة أقصى إحتياج مائي (100% من البخر نتح) عند أثر الري الناقص 50% من البخر نتح. خلصت التجربة إلي أن للحصول على أعلا قيم لقياسات نمو نخيل التمر يجب إتباع نظام الري بالتنقيط مع 100% بخرنتح.