Effect of Different Types of Emitters and Different Water Amount on the Growth Parameters of Date Palm (*Phoenix dactylifera)* under Dry-Land Conditions of Sudan

Abstract: The current study was conducted at Nobles Farm for Modern Systems located at 25km south east of Khartoum (longitude 32^{o} 42′ E, latitude 15^{o} 29′ N and altitude 377 m amsl) during two successive years 2012 and 2013 to investigate the effect of different emitters (turbo pressure compensating and turbo non-pressure compensating emitters) with different irrigation water amount (50%, 75% and 100% of ETc) on the growth parameters of one year old date palm (*Phoenix dactylifera).* The treatments used were two types of emitters with three irrigation water amount. Drip irrigation system was designed and installed to accommodate different treatments. Split plot experimental design with three replications was used in which the two types of emitters were assigned to the main plots while irrigation water amount were allocated to the sub plots. Crop water requirement was determined using CROPWAT version 8 computer model. A computer program (SAS statistical package) was used to analyze the data while the variations among the means were checked by the Least Significant Difference (LSD). The parameters tested were; crop water requirement, hydraulic performance growth parameters (plant height (cm), number of leaves per plant and number of offshoots per plant). The results showed that, the optimum crop water requirement of young date palm tree was found to be $20m^{3}$/tree/year. Growth parameters significantly ($P \leq 0.05$) affected by the different types of emitters and different irrigation water amount. Turbo pressure compensating emitter with 100% ETc irrigation water amount gave the highest mean values of growth parameters while turbo non-pressure compensating emitter with 50% ETc irrigation water amount ranked the least. Hence it is concluded that for optimum growth parameters, proper technical guidelines for system management, operation and scheduling should be developed and followed.

Keywrds: Emitter types; Water amount; Growth parameters; Date palm

تأثير أنواع النقاطات المختلفة وكميات الماء المختلفة على قياسات نمو نخيل التمر تحت ظروف السودان ذات الأراضي الجافة

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المستخلص: أجريت تجربة بمزرعة شركة نوبلز للأنظمة الحديثة التي تقع 25كم جنوب شرق الخرطوم (خط الطول 32 - 42ق، خط العرض 15 – 29 ش وإرتفاع 377م فوق مستوى سطح البحر) لعامين متتاليين (2012 و 2013) لبحث تأثير أنواع النقاطات المختلفة وكميات الماء المختلفة ع لى قياسات نم و نخيل التمر عمره سنة واحدة تحت ظروف ولاية الخرطوم، السودان. اشتملت المعاملات على نوعين من النقاطات (تيربو المعوضة للضغط وتيربة غير المعوضة للضغط) وثلاثة كميات ماء مختلفة (50%، 75% و 100% من بخرنتح المحصول). صمم نظام الري بالتنقيط ليلائم المعاملات المختلفة. نفذت التجربة بتصميم القطع المنشقة بثلاث مكررات وخصصت معملات النقاطات المختلفة للقطع الرئيسية ومعاملات كميات الماء المختلفة للقطع الفرعية. استخدمت برنامج الحاسوب CROPWAT-8 لتحديد الاحتياجات المائية. حللت البيانات باستخدام برنامج الحاسوب ساس(SAS) واستخدمت أقل فرق معنوي (LSD) لمقارنة المتوسطات. تضمنت القياسات الاحتياجات المائية، الخصائص الهايدروليكية، وقياسات النمو (ارتفاع الشجرة، عدد الأوراق وعدد الفسائل لكل شجرة). أوضحت النتائج أن الاحتياجات المائية لنخيل التمر كانت 20م^3/شجرة/سنة. قياسات النم و تأثرت إيجابا ($P \leq 0.05$) بمختلف أنواع النقاطات وكميات الماء المختلفة. النقاط تيربو المعوضة للضغط مع إضافة 100% من بخرنتح المحصول أعطى أعلى متوسط قيم لقياسات النم و مقارنة بالنقاط تيربو غير المعوضة للضغط. عليه خلصت التجربة إلي أن للحصول على قياسات مثلى للنم و فإنه يجب تشغيل وإتباع موجهات فنية صحيحة لإدارة وتشغيل وجدولة النظام.

NTRODUCTION

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With growing water scarcity and increasing competition across water-using sectors, the need for water savings and more efficient water use has increased (Batchelor, 1999). Under the limitations in water availability, it is required to develop new irrigation scheduling approaches focused to ensure optimal use of available water with efficient irrigation schedules, and not based on full crop water requirements. The determination of these efficient and effective irrigation schedules (including deficit irrigation strategies) require the accurate determination of water requirements for the main crops, in order to assist the farmers in deciding when and how much to irrigate their crops. If water can be applied efficiently in an irrigation field, water is saved and both crop quantity and quality are increased (Bush and Mohamed, 2016). Different irrigation techniques are available to irrigate crops, but not all of them are suitable for irrigation of date palms. The drip irrigation is one of the most efficient irrigation systems that are used to irrigate date palms. It can play a significant role in overcoming the scarcity of water mostly in water shortage areas to uniformly distribute 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). Emitter plays a crucial role in system performance. Therefore the hydraulic performance significantly affected by the optimum selection of emitters, lateral diameter and length, ideal manufacturer's coefficient of variation (CV%), slope and pressure variations (Al-Amoud, 1995). Pressure compensating emitters for trickle irrigation systems are manufactured so that the discharge from each emitter is uniform at arrange of different operating pressures. When the system reaches its designed operating pressure, pressure compensation becomes effective and the discharge rate remains the same for all higher pressure up to the maximum operating pressure. The discharge for the non-pressure compensating emitter increases directly with an increase in pressure, while that for the pressure compensating emitters remains nearly the same for its operating range (Roll, 2000 and Mohamed, 2013). Non-uniformity in drip irrigation potentially due to pressure differences, unequal drainage and unequal application rate also hinder to achieve full efficiency of system. So due to many advantages like efficient use of water, low cost, easy to manage and easy to automate, drip irrigation system is recommended as the best irrigation method for date palm plantation (Mohebi, 2005). Date palm producing regions are largely centered in the Near East and Africa, which are largely water scant regions of the world. The total date palm productivity in the world during 2008 was 7.05million tons (obtained from an area of 1,264,611ha) of which two-thirds came from Asia and the remaining from Africa, while Sudan produced about 4.77% of the world production (FAO, 2010). In Sudan, the date palm tree is considered as one of the most important fruit crops in its high nutrition values and plays an important role in the economy (Sedig and Abd-Alwahab 1999). The date palm plantations are irrigated with the conventional basin irrigation system. The quantity of irrigation water applied depends on the farmer's judgment and the plantations either receive irrigation water in excess or less than required. In Khartoum State there are some plantations which use drip system for irrigation. The management of these systems (amount to be applied and irrigation frequency, with regard to crop water requirement) is not made on scientific basis but on the experience and judgment of the farmer. The irrigation practice of Sudan farmers depends more on the amount of water that is available and the farmer's experience than on the real water requirement of plants (Bush and Mohamed, 2016). Due to the absence of proper water management; there is an urgent need for optimum use of water for agriculture and an extra emphasis should be directed towards water management to prevent water pollution or deterioration of water quality. Information concerning water requirement of date palm is necessary for designing irrigation system and managing water properly; but there is lack of data on the water requirement and irrigation scheduling of date palm. Therefore the objectives of this study was to investigate the effect of different emitters (turbo pressure compensating and turbo non-pressure compensating emitters) with different irrigation water amount (50%, 75% and 100% ETc) on the growth parameters of Barhi cultivar date palm (*Phoenix dactylifera).*

2. Materials and Methods:

2.1 Study area:

This study was conducted at Nobles Farm for Modern Systems located at 25km south east of Khartoum (longitude 32^{o} 42′ E, latitude 15^{o} 29′ N and altitude 377 m amsl) during two consecutive years 2012 and 2013 to investigate the effect of different emitters (turbo pressure compensating and turbo non-pressure compensating emitters) with different irrigation water amount (50%, 75% and 100% ETc) on the growth parameters of date palm (*Phoenix dactylifera)*. The climate is semi-arid with low relative humidity and daily mean maximum and minimum temperature are 35.4^{o} C and 21.2^{o} C, respectively. The annual rainfall is limited and usually occurs in the form of short intense thunder storms. This means that water is deficient and crop production must be based on irrigation.

2.2 Experimental Layout:

The treatments used were two types of emitters (turbo pressure compensating and turbo non-pressure compensation emitters) with three irrigation water amount (50%, 75% and 100% ETc). Drip irrigation system was well designed and installed to accommodate different treatments. The treatments were arranged in split plot design with three replicates. The two emitters were allocated to the main plots and the three irrigation water amounts were assigned to the subplots.

2.3 The component of 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 seven valves 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: turbo pressure compensating and turbo non-pressure compensating emitters of 4 L/h rated discharge were used in this system. Four emitters were fixed for each date palm tree.

2.4 Determination of date palm water requirement:

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 and FAO, 2010).

ETc = ETo*Kc*Ks*Kr …………………………………….. (1)

Where:

ETc = Crop evapotranspiration (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

$$GC\ (\%) = \frac{\text{Shaded area per tree}}{\text{Area per tree}} \times 100 \qquad (2)$$

Where:

D = Average width of measured shaded area between two trees.

GC = Ground cover (%).

The reduction factor (Kr) was estimated using equation (3) as suggested by Keller and Bliesner (1990) and Esmail (2002):

$$Kr = 0.1GC^{0.5} \qquad (3)$$

Where:

Kr = the reduction factor.

GC = ground cover (%).

2.4.1 Reference crop evapotranspiration (ETo)

Reference crop evapotranspiration (ETo) can be calculated by Penman-Monteith equation as stated by Smith *et al*., (1998).

ETo =

$$\frac{0.408\Delta(Rn-G)+\gamma\left(\frac{900}{T}+273\right)U_2(es-ea)}{\Delta+\gamma(1+0.34U_2)} \quad ....(4)$$

Where:

ETo = Reference crop evapotranspiration (mm day^{-1})

R_n = Net radiation at crop surface ($Mjm^{-2}day^{-1}$)

T = Average temperature at 2m height (^oc).

e_s = Svp, kPa e_a = Actual vp (kPa)

(e_s –e_a) = Saturation pressure deficit for measurement at 2m height (kPa).

U_2 = Wind speed at 2m hight (ms^{-1}).

Δ = Slope of vapor pressure curve (k Pa ^oc).

γ = Psychometric constant (k Pa ^oc)

900 = Coefficient for reference crop (Kj Kg day^{-1})

0.34 = Wind coefficient for the reference crop (S m^{-1})

G = Soil heat flux (Mj m^{-2} day^{-1})

Soil heat flux (G) may be ignored if the period is less than 10 days which can be calculated according to the following equation:

$G_{month} = 0.14(T_{month} - T_{month-1})$ ….. …………………… (5)

Where:

T_{month} =Average temperature for the mentioned month (^oC)

$T_{month-1}$ = Average temperature for the month before (^oC)

$e_a = e_s \times$ relative humidity as a fraction (Esmail, 2002)…………….. (6)

2.4.1.1 Wind speed formula

The following formula is used to adjust the wind speed data from 20m to the standard height of 2m as stated by Smith *et al*. (1991).

$$U_2 = U_z * \frac{4.85}{Ln\left(\frac{Zm - 0.8}{0.15}\right)} \qquad (7)$$

Where:

U_z = mean wind speed measured at height (z) (m/sec).

U_2 =mean wind speed measured at height 2m (m/sec).

Zm = height at which wind speed is measured (m). When there is no enough data to calculate $U_{2,}$ it is possible to use the International Average Wind Speed (1 +3)/2 =2m/sec.

2.4.2 Crop Coefficient (KC)

Crop coefficient is mainly controlled by the crop characteristics namely the resistance to transpiration of different plants. To maintain good growth and high yields of good quality a regular water supply is needed throughout the year with a possible exception just prior and during harvest and at winter time. The crop coefficient was determined by the following equation (Hess, 1996)

KC = (KCb . KS) + Ke …………………………………… (8)

Where:

KC = the basal crop coefficient when the water is not a limiting factor for plant growth.

KCb = set equal to 0.8 (Doorenbos and Pruitt, 1977).

KS = soil water availability factor (0 - 1).

Ke = soil water evaporation coefficient (equal to 0.1 from experimental data measuring soil evaporation under the canopy at different locations).

2.5 The amount of water applied:

The amount of irrigation water was applied to each tree per irrigation as a portion of crop evapotranspiration (ETc) as follows:

1. Applying 100% of crop evapotranspiration.
2. Applying 75% of crop evapotranspiration.
3. Applying 50% of crop evapotranspiration.

The aforementioned treatments were determined using the following equation described by Makki and Mohamed (2005).

$$V = \frac{ETc * I * A}{Ea} \qquad \text{………………………………………………} (9)$$

Where:

V = volume of water to be applied to each tree per irrigation (liters).

ETc = crop water requirement (mm/day).

I = irrigation frequency (days).

A = the area specified for each tree m^2.

Ea = application efficiency.

2.6 The daily water use (liter/tree/day):

The daily water use by date palm tree is calculated by the relation mentioned by Esmail (2002) as follows:

The daily water use = $\frac{ETc*Ar}{Ea}$ …………………………… (10)

ETc = Crop water requirement (mm/day).

Ar = Area specified for each tree m^2.

Ea = Irrigation application efficiency.

2.7 Irrigation set time for drip:

It is the time required to apply irrigation. Vermeiren and Gobling (1980) stated that the estimation of the maximum time of application is based on providing water for plant when it can use it.

$$T = \frac{ETc \times Se \times Sl \times k}{E \times Q} \quad \text{……………………………………} (11)$$

Where:

T= Irrigation set time (h).

ETc =Crop evapotranspiration (mm/day)

Se = Emitter spacing (m).

Sl = Lateral spacing (m).

Q = Emitter discharge (l/h).

E = Emitter efficiency (%).

k = Constant (in metric system =1)

2.8 System capacity:

Capacity depends on the irrigation application rate, time of irrigation, and interval between irrigations. Wu *et al.* (2007) suggested an equation to calculate the system capacity as follows:

$$Q = \frac{(Ig \times A)}{T} \quad \ldots\ldots (12)$$

Where:

Q = drip irrigation system capacity (m^3/h).

Ig = gross irrigation water requirement (m).

A = the global area to be irrigated (m^2).

T = irrigation time (h).

2.9 Measurement of rainfall:

Daily rainfall was measured using the standard ordinary rain gauge exposed 1 m above ground level away from buildings and trees. The diameter of the standard gauge is 5 inches (12.7 cm). There was 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 was used to give a continuous record of rainfall, this type of rain gauges is very important because it gives the intensity of rainfall (Adam, 2014).

2.9.1 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):

Pef = E. Ptot + A ………………………………………… (13)

Where:

Pef = Effective rainfall over the growing season.

E = Ratio of consumptive use of water (cubic) to Ptot.65.

Ptot = Total rainfall over the growing season.

A = Average irrigation application.

2.10 Parameters for Emitters Evaluation:

The following parameters were used to evaluate drip irrigation system:

a. Uniformity of water application (Cu):

Christiansen's Cu (%) evaluates the mean deviation, which is represented in ASAE standards (1999) as follows:

$$Cu\ \% = 100\left[1 - \frac{1}{nqa}\sum_{i=1}^{n}|qi - qa|\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

Where:

q_a = the average emitter discharge rate (m^3/s).

q_i = the flow rate of the emitter (m^3/s).

b. Distribution uniformity (DU):

Low quarter distribution uniformity (DU) (Merriam and Keller, 1978) as applied to all types of irrigation systems can be expressed as follows:

$$DU = 100\left[\frac{q_m}{q_a}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

Where:

q_m = the average flow rate of the emitters in the lowest quarter.

q_a = the average emitter discharge rate (m^3/s).

c. The coefficient of variation of emitter flow (Cv):

The coefficient of variation of emitter flow (Cv) evaluates the variability of flow and was computed by dividing the standard deviation by the average emitter discharge rate. Manufacturers usually publish the coefficient of variation for each of their products and the system designer must consider this source of variability (ASAE, 1999). Cv can be expressed as:

$$Cv = \frac{Sq}{qa} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (16)$$

Where:

Cv = the coefficient of variation of emitter flow.

S_{q} = the standard deviation of emitter flow rate.

q_{a} = the average emitter discharge rate (m^3/s).

2.11 Date palm growth parameters:

The date palm parameters measured included the following:

a. Plant height (cm)

It was measured monthly on a random sample of ten plants per submain line. A measuring tape was used to measure the plant height (cm). It was determined from the ground surface to the tip of the plant.

b. Number of leaves per plant

It was counted monthly on a random sample of the ten plants per submain line.

c. Number of offshoots per plant

The average number of offshoots per plant was counted from the ten plants randomly selected in each submain line.

2.12 Data analysis:

A computer program (SAS statistical package) was used to analyze the data. The variations among means were checked by the least significant difference (LSD).

3. Results and Discussion:

3.1 Crop water requirement of young date palm and infiltration rate:

The results showed that, the optimum crop water requirement of one year old date palm tree was found to be 20m^3/tree/year. This result agreed with Al-Amoud *et al.* (2012) who estimated the average daily date palm water use, was 184.4 l/day and the total annual date palm water use have ranged between 59.4 and 80 m^3/tree. The infiltration rate was 216mm/h during the first five minutes and it is considered very high while at the end decreased to reach 39.5 mm/h. The high initial infiltration rate was due to the soil type (sandy loam) as mentioned by Michael (1978). So due to the soil type, date palm tree has the ability to maintain its consumptive use under certain conditions and has developed a root system capable to search for moisture from the deepest soil profile (Hassan, 2001).

3.2 Effect of different types of emitters on the growth parameters of date palm

As shown in Table 1. The growth parameters significantly ($P \leq 0.05$) affected by the different types of emitters. Turbo pressure compensating emitters recorded the highest values as compared to turbo non-pressure compensating emitters. This may be due to the fact that turbo pressure compensating emitters have high performance than turbo non-pressure compensating emitters so that the discharge from each emitter is uniform at arrange of different operating pressures. These results agreed with Bush *et al.* (2016) who reported that, if water can be applied efficiently in an irrigation field, water is saved and both crop quantity and quality are increased.

3.3 Effect of irrigation water amount on the growth parameters of date palm

As presented in Table 2. different irrigation water amount significantly ($P \leq 0.05$) affected the growth parameters. Applied 100% ETc gave the highest values of growth parameters as compared to 50% ETc water applied. This may be due to the fact that, water applied to satisfy 100% ETc was sufficient to meet the crop water requirement. This result agreed with Ali (2013) who mentioned that, there were significant effects on stability and vegetative growth of date palm at 100% water regime in the different irrigation treatments (100%, 80% and 60% of Class A Pan).

The interaction between two types of emitters and three irrigation water amounts significantly ($P \leq 0.05$) affected the growth parameters. Turbo pressure compensating emitters with irrigation water amount 100% ETc gave the highest values of growth parameters as compared to Turbo non-pressure compensating emitters with 50% ETc irrigation water amount. This may be due to the fact that turbo pressure compensating emitters have high performance than turbo non-pressure compensating emitters so that the discharge from each emitter is uniform at arrange of different operating pressures as stated by Bush *et al.* (2016). This agreed with the results obtained by Ibrahim *et al.* (2012) who reported that, the interaction of irrigation system and amount of watering significantly affected the growth parameters.

Table 1. Effect of different types of emitters on the growth parameters of date palm

Emitter	Cu%	Du%	Plant height (cm)	No. of leaves/plant	No. of offshoots
Turbo P.C	92[a]	89[a]	90[a]	36[a]	2[a]
Turbo non-P.C	88[b]	84[b]	75[b]	33[b]	1[b]
LSD	3.2	4.1	7.8	2.5	0.8

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

Table 2. Effect of irrigation water amount on the growth parameters of date palm

Water amount	Plant height (cm)	No. of leaves/plant	No. of offshoots
100% ETc	110[a]	40[a]	3[a]
75% ETc	90[b]	37[b]	3[a]
50% ETc	80[c]	27[c]	1[b]
LSD	7.3	2.4	1.6

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

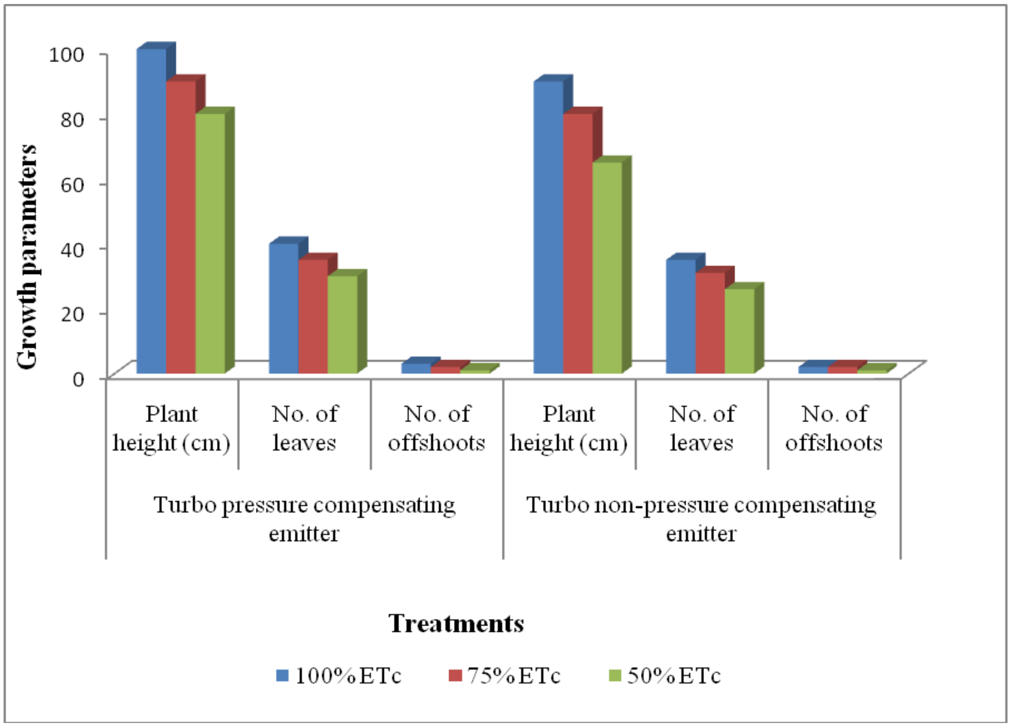

Figure 1. The interaction between two types of emitters and three irrigation water amounts and their effect on growth parameters

4. Conclusion:

Drip irrigation system was well designed and installed to accommodate different treatments. The crop water requirement of one year old date palm was found to be $20m^3$/tree/year. Turbo pressure compensating emitter with 100% ETc irrigation water amount gave the highest mean values of young date palm growth parameters.

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