Interlaced impacts of solar radiation energy and amounts of water on some forest trees growth parameters

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Abstract; This study was carried out at Serapium forest at Ismailia governorate and Luxor forest at Luxor governorate. The experiment was conducted to assess the influence of different amounts of water with different Solar Radiation Energy (SRE) on some growth parameters [Height and root collar diameter (RCD)] for two forest tree species (*Azadirachta indica*and *Gmelina arborea*). Thus; experiment was laid out on complete randomized block design with two factors. First factor is amount of water which comprise into five treatments (Q_1, Q_2 Q_3, Q4 and Q_5) with average (130%; 1.15%; 100%; 85%; 70%) respectively from total water applied. Second factor is two Solar radiation energy (SRE) with [6902.8 MJ/m^2/year at Ismailia and 7717.1 MJ/m^2/year at Luxor] during period November 2013 to March 2015. The results revealed that the water quantities has a significant influence on total tree Height for *A.indica* especially between Q_2 and Q_5; however; amounts of water have not any significant influence on both tree height and (RCD) for *G.arborea*. Moreover; at Luxor the SRE recorded a best value for *A.indica* tree height comparing with SRE at Ismailia by 2.1mm/MJ.m^{-2}. On the other hand; *G.arborea* obtained a highest value for tree height parameter at Ismailia (SRE) by 1.38mm//MJ. $m^{-2.}$ Finally; effective water use for *A.indica* tree height at Luxor is (51.3cm/$m^{3)}$ and at Ismailia is (40.7cm/m^3) but with *G.arborea* the effective water use is (30.48cm/m^3) at Ismailia and (23.7cm/m^3) at Luxor.

[A.K. Mahmoud and A.M. El-Gindy. **Interlaced impacts of solar radiation energy and amounts of water on some forest trees growth parameters.** *J Am Sci* 2016;12(1):87-95]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). http://www.jofamericanscience.org. 12. doi:10.7537/marsjas12011612.

Key words: solar radiation energy; water quantities; forest tree and water use.

1. Introduction

Numerous of countries have suffering from water scarcity and impairment management for water resources, thus; they focusing to deal with this problematic by more rationalized and efficient manner than ever before. Therefore, using treated waste water is one of the alternative water resources for irrigation especially in Egypt which located in arid and semi arid region. However; there are many obstacles will face agricultural system when using this type of water. For instance; a) finding means of lowering the current level of water demand by some efficient water use techniques, and b) promote economic return to the farmers to enhance economic incentives, these can be obtained through high production and increasing the water productivity using new irrigation approach. c) The climatic parameters and total solar radiation energy. Likewise; impact low quality water in environment which compulsory to more mentoring and management.

First; the most important factors at Agricultural system that influence on plants development is the solar radiation intercepted by crop. The solar radiation brings energy to the metabolic process of the plants. The principal process is the photosynthetic assimilation that makes synthesize vegetal components from water, CO2 and the light energy possible. A part of this, energy is used in the evaporation process inside the different organs of the plants, and also in the transpiration through the stomas. The productivity of a crop depends on the ability of plant cover to intercept the incident Radiation, Deficiencies in water and nutrient inputs may reduce the rate of leaf growth, reducing yield below optimum levels due to insufficient energy capture (Gardner *et al.*, 1985). Moreover; some forest tree has a different response for solar radiation energy for instance; *Azadirachta indica* requires large amounts of light, but it tolerates fairly heavy shade during first year.(Noad & Birnie, 1989).

Second; Waste water use in the irrigation of tree plantations *Eucalyptus tereticornis*, *Populus deltoides and Leucaena leucocephala*. (CSSRI. 1989); For all three species, trees irrigated monthly with sewage water showed a higher growth than trees irrigated with well water at the same frequency: the *Eucalyptus* was 6 percent taller after 48 months; the *Leucaena* was 12 percent taller after 36 months; and the poplar was 4 percent taller after 24 months.

Thus; the proportions between height and diameter, between (crown height & diameter), between (biomass & diameter) follow rules that are the same for all trees, big or small, as long as they are growing under the same conditions (King, 1996; Archibald & Bond, 2003; Dietze *et al.*, 2008). This is the basic principle of allometry and can be used to predict a tree variable (typically its biomass) from another dimension (e.g. its diameter) (Dhôte, 1996); used a linear model to model tree diameter growth: below a certain circumference threshold, trees are overtopped and no longer grow; above the threshold their growth shows a linear relationship with tree circumference. The threshold and slope of the relationship change with stand age and silviculture treatments.

On the other hand; the height growth of dominant trees is still the main basic principle in most growth and models (Skovsgaard & Vanclay, 2008). The principle is recapitulation by (Alder; 1980) in the following sentence: "The height / age / fertility index relationship is key to predicting the growth of homogeneous stands.

Clearly, there is some tantalizing potential for using treated wastewater for irrigation forestry and agro-forestry, but much research is still to be done before this potential can be realized. Thus; The aim of this study is to test the influence of five water quantities with average (11.1, 9.8, 8.6, 7.3 and 6.1 L/Tree/day) at two locations Luxor and Ismailia for different solar radiation energy on two forest tree species parameters [tree height and root collar diameter (RCD)] beside the effective water use; to determine the best amount of water and the best location which acquiring a significant results under such condition.

2. Material and Methods

Experimental location

Table 1: Climatic characteristics at Ismailia governorate.(**(FAO AQUASTAT 2015)**

Month	Prc. mm/m	Wet days	Tem. max °C	Tem min. °C	Hum. %	SRE $MJ/m^2/d$	Wind (2m) m/s	ETo mm/d
Jan	5	4.5	19.1	13.7	58.9	11.6	2.2	2.4
Feb	5	3.5	20.7	14.9	56.1	14.4	2.6	3.2
Mar	5	2.5	23	11	52.1	17.9	2.8	4.2
Apr	2	1.1	28.1	14.6	46	21.4	2.8	5.7
may	2	0.6	31.5	17	45.1	23.9	2.8	6.8
Jun	0	0	34.4	20.1	48.4	26.1	2.8	7.5
Jul	0	0	35.2	21.8	51.9	25.5	2.5	7.3
Aug	0	0	34.9	22	54.6	24	2.4	6.8
Sep	0	0	32.8	20.4	56.4	21.1	2.4	5.7
Oct	1	1	29.7	17.5	57.2	16.9	2.4	4.6
Nov	5	2	25.1	13.5	59.5	13.1	2	3.1
Dec	4	3.4	20.6	9.7	61	10.8	2	2.3
average								**4.9**

Table 2: Climatic characteristics at Luxor governorate.(**(FAO AQUASTAT 2015)**

Month	Prc. mm/m	Wet days	Tem. max °C	Tem min. °C	Hum. %	SRE $MJ/m^2/d$	Wind (2m) m/s	ETo mm/d
Jan	0	0.2	22.4	5.8	51.2	15.3	2.3	3.3
Feb	0	0.1	24.7	7.3	43.6	18.15	2.4	4.2
Mar	0	0.2	28.8	11.2	35.7	20.8	2.5	5.6
Apr	0	0.2	34	16.2	29.4	23.2	2.7	7.4
may	0	0.3	37.7	20.0	25.7	25.3	2.5	8.3
Jun	0	0.1	40.4	22.7	26.3	26.5	2.5	9
Jul	0	0.1	39.8	23.6	29.4	26.1	2.3	8.6
Aug	0	0.1	39.5	23.2	31.4	25.25	2.2	8.1
Sep	0	0.1	37.9	21.3	34.9	22.5	2.4	7.5
Oct	1	0.3	34.4	17.4	39.4	19.35	1.9	5.6
Nov	1	0.2	28.4	11.9	47.6	16.25	2	4.1
Dec	1	0.2	23.8	7.4	52.9	14.7	2	3.2
average								**6.2**

(*Prc.* = Precipitation; *Wet days* = Number of days per month with >0.1mm of precipitation; *Tmp. min/max* = minimum/maximum temperature; *hum.* = relative humidity; *SRE*= solar radiation energy of day length; *Wind* (*2m*) = wind speed at 2m; *ETo*= Reference evapotranspiration)

The experimental was carried out at Serapium and Luxor forest; throw the project "Establishment of plantation forests and development of sustainable forestry in desert lands of Egypt using sewage water education and research project"; which located in north eastern and upper of Egypt,. The study site, established in late November of (2013-2015), sites where fall into an arid area. Ismailia site is about 30 m above sea level with an annual rainfall of 29 mm/year, temperatures of 21.6 °C, relative humidity of 53.9%, and wind speed of 2.5 m/s. The total annual evapotranspiration (ETo) is 1821 mm/year (table [1]). Likewise; Luxor site where located about 186m above sea level with annual climate data [3 mm/year for rainfall-2280mm/year for (ETo)] (table [2]).

The soil of experimental at two sites are sandy texture, none saline, and none calcareous. Silt and clay content; average 3.9% and 4.7% respectively for Ismailia; and 5% and 3.5% respectively for Luxor. Thus; both field capacity and available water are very low 5.6 %, 4.5 % for Ismailia and 5.4%, 3.9% for Luxor. Moreover; EC. soil conductivity 1.37dS/m for Ismailia and 1.05dS/m for Luxor.

Experiment and irrigation systems design

Experiment was laid out on complete randomized block design with two factors. First factor is amount of water which comprise into five treatments (Q_1, Q_2, Q_3, Q4 and Q_5) with average (11.1, 9.8, 8.6, 7.3 and 6.1 L/Tree/day) respectively (Fig. 1 & 2 &3). Second factor is two sites with different solar radiation energy (6902.8 MJ/m^2/year at Ismailia and 7717.1 MJ/m^2/year at Luxor] during period November 2013 to March 2015.

Furthermore; experiment was evaluate two tree species (*Azadirachta indica*and and *Gmelina arborea*) which distributed into three blocks each block (88m * 88m) is subdivided into four plots with dimension (22m * 22m). Each plot contains one species with distance for plantation (4.4m* 2.2m).

The most commonly used Kc values come from the FAO "Irrigation and Drainage Paper #56: Crop Evapo-transpiration: Guidelines for Computing Crop Water Requirements." Unfortunately, the FAO database does not provide Kc value for all possible crops. Kc values for special crops such as (*Azadirachta indica* and *Gmelina arborea)* should be based on the nearest crop category (e.g., seed oil crops or citrus trees), (FAO, 56). With an average (Kc min = 0.15). Further; Crop water requirement and total water applied.

[Table (2)] was calculated using an average Reference Evapo-transpiration (ETo) and the Crop coefficients (Kc) by the following equations.

ETc = ETo * KC (1)

Where;

Etc Crop Evapotranspiration, (mm/day).

Eto Reference Evapotranspiration, (mm/day).

Kc Crop coefficients.

IRn= ETc – Peff (2)

where;

IRn Net irrigation requirement, (mm/day).

ETc Cropevapotranspiration,(mm/day).

Peff Effective rainfall, (mm/day).

IRt= IRn/Ea (3)

where;

IRt total water applied (mm/day).

IRn Net irrigation requirement, (mm/day).

Ea Overall irrigation efficiency, (%). Approximately (95%)

Table 2: Total water applied for tree secrecies per day.

	Average (ETo) mm/day	Average (KC)	Etc (mm/day)	IRt (mm/day)	(L/tree/day)
Ismailia	4.9	0.15	0.73	0.773	7.7
Luxor	6.2	0.15	0.93	0.97	9.7
average	5.5	0.15	0.82	0.86	8.6

Measurements and calculations

Effective water use on growth parameters (Ht, RCD, Cr with equation (4).

EWUG = [Hi,RDC] / IRR_i ()

Where:-

EWUG Effective water use growth (Cm/m^3).

Hi Height of tree (Cm).

RCD Root collar diameter (cm).

IRR_i Total Irrigation water applied (m^3)

Root collar diameter (RCD) for a single-stemmed tree, RCD is equal to the single diameter for a multi-stemmed tree; RCD is calculated from the diameter measurements of all qualifying stems (≥ 1.5" diameter and at least one foot in length). Meeuwig and Budy 1981, Batcheler 1985

$$RCD = \sqrt[n]{\sum_{1}^{n} (stim\,\text{dim}\quad)^2} \qquad (5)$$

Where:

RCD Root collar diameter (cm)

n Number of stems at RCD

Statistical analysis for modelling:

The data were analyzed using the two way ANOVA on complete randomized block design procedure with Duncan's HSD test at p<0.05 using the COSTAT 3.03 System software.

The simple regression models with predictor variables X_1;……. ; Xpcan be describe by equation (6).

$$y = B_0 + B_1X_1 + \ldots\ldots\ldots\ldots + B_pX_p + k \qquad (6)$$

Where:

Variable y, called a response or dependent variable, depends on another variables $X_{(1..p)}$ which is called the independent or predictor variable (also called the regressor variable), B_0 is intercept, $B_{1\text{-}P}$ is the slope parameters and the variability of the error *(k)* is constant for all values of the repressor.

Fig.(1) *A. indica* under different water quantities and measurement for growth parameters.

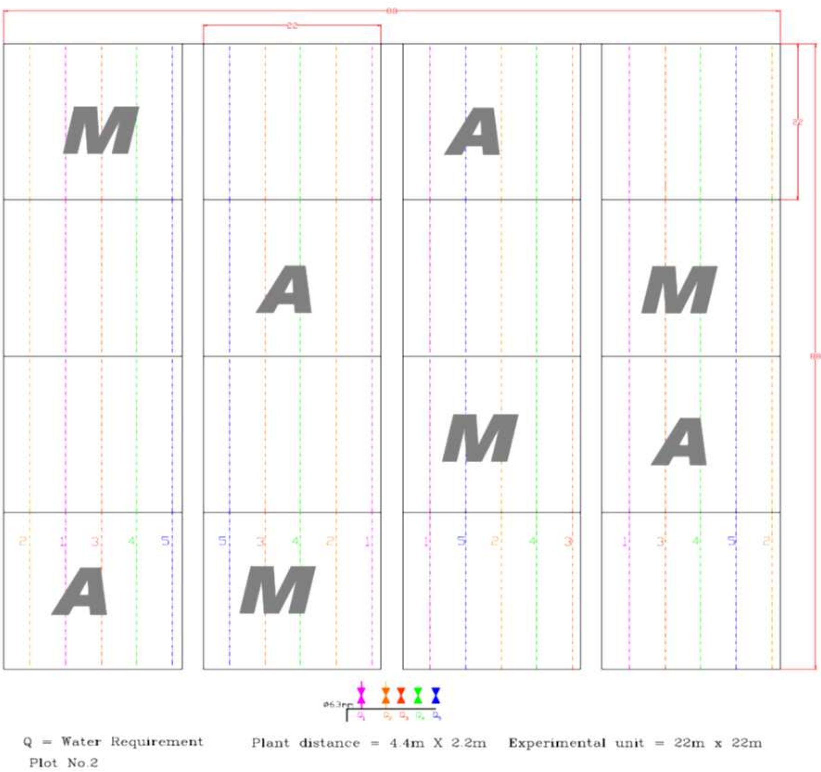


Fig.(2) Layout of Experiment with randomizes distribution for water treatments and two tree species *A. indica (A)* and *G.arborea (M).*

Fig.(3). Irrigation network system (valve box, flow meters and controller) (installation pipes).

3. Result and Discussion

a) Influence different water quantities on growth parameters:

Total tree height.

An impact different amount of water on two tree species is obviously clear on total height parameter as indictor for growth. As shownin fig.(4) that Q_2; amount of water; has a significant influence value (159.4cm) for total height comparing with Q_5 specially for *A. indica.* This because; that the *A. indica* is tolerates and sensitive. It quickly dies in water logged soils **(Alex. *et al.*, 2004)**. Thus; high amount of water Q_1 gives a low value comparing with Q_2. likewise; the best amount of water which recommended irrigating this type of tree is Q_2. On the other hand; with *G. Arborea* there are not any significant influences for amounts of water on total tree height. But; the best value recorded with Q_2 (87.92cm) for total height and the lowest value obvious with Q_3 (76.75cm). Inasmuch as; that the available water content in the environment gradually decreases, stomata conductance decreases substantially, reducing transpiration, but without significantly affecting photosynthesis, because stomata closure reduces the flow of water vapour more than the flow of CO_2 (**Kozlowski and Pallardy, 1997**) resulting in reduced leaf area and growth, decreased root development and expansion, affecting plant height and canopy establishment (Martínez et al., 2002). Thus; Transpiration rates decreased with the age of the trees (**Rojas *et al.*, 2012**). So, *G. arborea can* irrigate by low amount of water Q_5 and give a good response at the growth parameters.

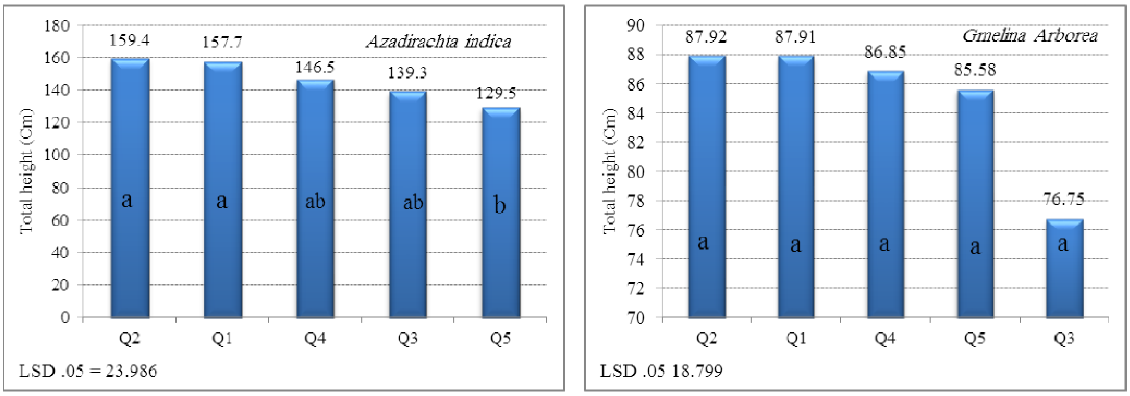


Fig.4 Influence of different irrigation systems on total height for tree species.

Root collar diameter.

Furthermore; as shown in fig (5); the different water quantities have not any significant influence on root collar diameter (RCD) for both tree species. For instance; under *A. indica* the RCD recoded a highest value by 34.65mm with Q_2 and low value obvious with Q_5 by (28.6mm). In addition; with *G.Arborea* a good response for tree height came under Q_5 by (33.35mm) but the lower value recorded with Q_3 (25.57mm). Inasmuch as; the physiology tree behaviour with low amount of water stomata conductance decreases substantially, reducing transpiration, but without significantly affecting photosynthesis, because stomata closure reduces the flow of water vapour more than the flow of CO_2 (**Kozlowski and Pallardy, 1997**) resulting in reduced leaf area and growth, decreased root development and expansion, affecting plant height and canopy establishment (Martínez et al., 2002). Thus; Transpiration rates decreased with the age of the trees (**Rojas *et al.*, 2012)**. So, the best value for tree height and RCD were recorded with low amount of water Q_5.

In contrast; with *A.indica* the best value for both RCD and tree height were obvious with Q_2.beacause, that the *A.indica* is tolerates and sensitive. It quickly dies in waterlogged soils **(Alex. *et al.*, 2004)**.

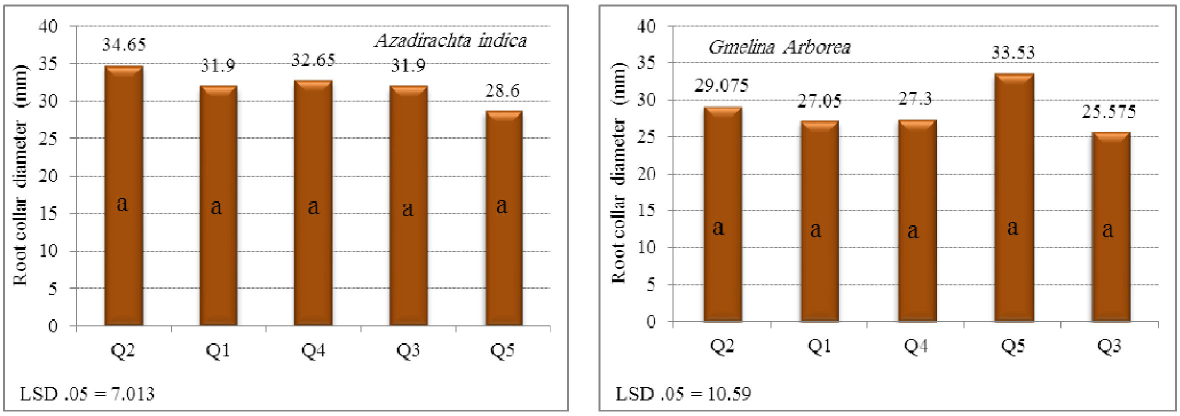


Fig.5 Influence of different water quantities on root collar diameter for tree species

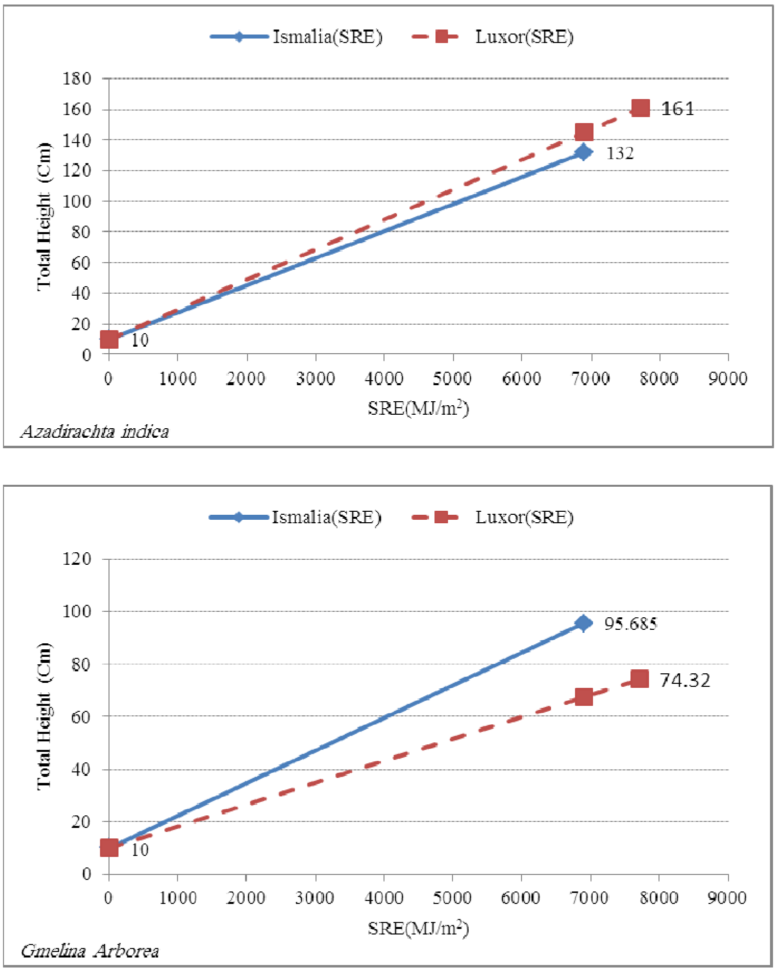


Fig. 6 Influence of Solar radiation energy on total height for tree species.

b) Influence of solar radiation energy on growth parameters:

Total tree height.

As shown in (Fig.6) *A.indica* has a high responses value for Luxor (SRE) comparing with Ismailia (SRE) on tree height parameter by (29mm). However; the variation between values are not a significant differentiation with (LSD 0.05= 30.45). But a good response comes with (SRE) of Luxor because that the *A.indica* requires large amounts of light, but it tolerates fairly heavy shade during the first year (Noad T, Birnie A. 1989) generally, plants grown in tropical climatic conditions experienced significantly high irradiance leading to a strong midday depression photosynthesis. Further; with *G. arborea* the response of tree height has a highest mean value under SRE in Ismail which recorded (95.68cm) and (74.32cm) under SRE in Luxor. However; the variation between values are not a significant differentiation with (LSD 0.05= 53.21). Inasmuch as; After 2 weeks of the dry season, plants began the leaf abscission process in response to the water deficit, a characteristic considered as a resistance mechanism, because it reduces water loss through transpiration; (Gindaba ***et al.,*** 2004). Finally; the rate of *A.indica* development at Luxor is (2.1mm/MJ m^{-2}) and (1.91mm /MJ. m^{-2}) at Ismailia. Moreover, for *G. arborea* the rate of expansion is (1.38mm//MJ m^{-2}) at Ismailia and (0.96mm / MJ. m^{-2}) at Luxor.

Root collar diameter.

According to the data obtained for RCD of *A.indica* at Ismalia and Luxor there are not any significant influence for (SRE) at (LSD.05 = 11.822) where the different between two values is (1.78mm) [Fig.7]. On the other hand; value of (RCD) for *G. arborea* at Ismailia recorded (34.71mm) and (22.3mm) at Luxor. Inasmuch as; that the rate of growth for *G.arborea* is better at Ismailia than Luxor. However; the differentiation between two values are not significant at (LSD0.05=12.775). Thus; the rate of growth for (RCD) related to (SRE) is (0.005mm/ MJ. m^{-2}) and (0.002mm/ MJ. m^{-2}) for *G.arborea*at Ismailia and Luxor respectively. Furthermore; for *A.indica* the rate of growth related to (SRE) is convergent value between (Luxor and Ismailia) approximate (0.004mm/MJ. m^{-2}).

c) Effective water use on some growth parameters for trees.

Rationally; there are a highest response for both RCD and trees height to unit of water with a various impact related to location (Ismailia or Luxor). For instance; as shown in table (3) with *A.indica* the best effective water use came at Luxor by (51.3cm/m^3) for tree height parameter and (9.9mm/m^3) for RCD. However; at Ismailia, the values recoded (40.7cm/m^3) and (10.4mm/m^3) for tree height and RCD respectively.

Noticeable; that the effective water use under *G. Arborea* acquired highest value for tree height and RCD at Ismailia by (30.48cm/m^3) and (11.05mm/m^3) respectively. On the other hand; at Luxor *G.Arborea* obtained low response value comparing with Ismailia which recorded (23.7cm/m^3) for tree height and (7.1mm/m^3) for RCD.

Table 3: Response of (RCD) and Total Height on unit of water for different tree species.

Items	Total tree high cm/m^3		Root collar diameter (RCD) mm/m^3	
	Ismailia	Luxor	Ismailia	Luxor
Azadirachtaindica	40.7	51.3	10.4	9.9
Gmelinaarborea	30.48	23.7	11.05	7.1

d) Statistical model

Occasionally; a model is a schematic representation of the conception of a system or an act of mimicry or a set of equations, which represents the behaviour of a system (Murthy, 2003). Furthermore; Crop and plant growth model is a very effective tool for predicting possible impacts of different factors on crop growth and yield. Crop growth models are useful for solving various practical problems in agriculture. Thus; the regression models (using multiple regression at statistical program COStat which collect all parameters to determine the total tree height for various species under such conductions are:-

$$H_A = 2.596^* RCD_A + 10.744^*Q + 0.0355^*SRE - 226.956 \quad (R^2=0.7328)$$

$$H_m = 1.38^* RCD_m + 3.007^*Q - 0.0068^*SRE + 86.855 \quad (R^2=0.560)$$

Where:-

H_A = Total Height for *A. indica* (Cm).

H_m = Total Height for *G. Arborea* (Cm).

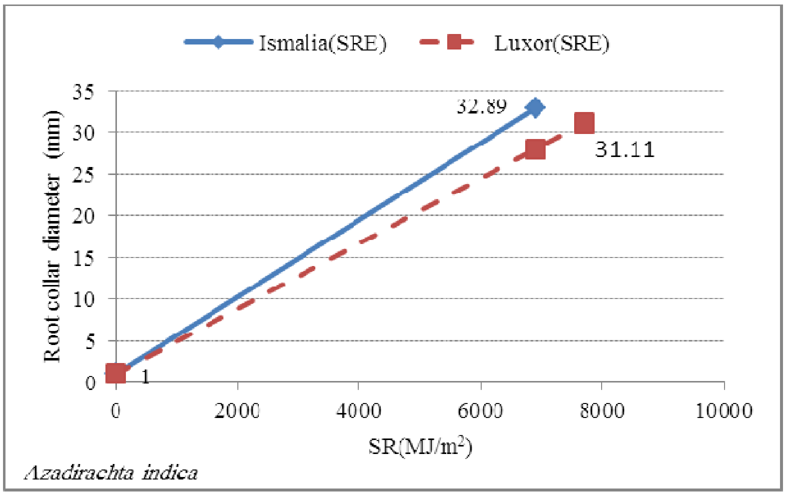
RCD_A=Root Collar Diameter for *A. indica* (mm).

RCD_m=Root Collar Diameter for *G.Arborea* (mm).

SRE = solar radiation energy (MJ/m^2/year)

Q = total water applied (m^3/tree/year).

Hence the previous models are represents the behaviour of a system under such conditions by knowingly three parameters total water applied per tree during year, Root Collar Diameter (RCD) and solar radiation energy to predicate the total tree height for each tree.



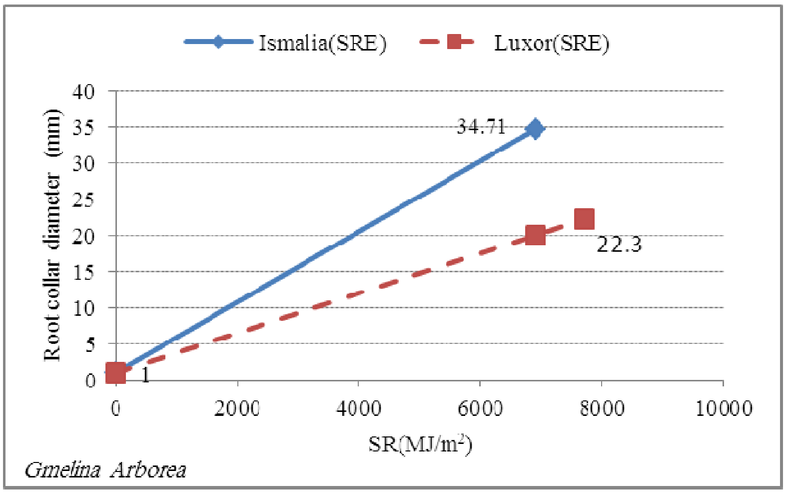


Fig.7 Influence of Solar radiation energy on root collar diameter for tree species

Conclusions

Noticeable; that the different solar radiation energy has a significant contribution for different growth parameters. Hence, choice from various location is considered vital processes to ensure the success of any agricultural project specially when establish a forest at desert land. From the previous data analysis; the first choice when planted *Azadirachta indica*is Luxor then recommended Ismailia as a second choice. In contrast; with *G. Arborea* has a good value for growth parameters at Ismailia than Luxor. Moreover; there are not a significant influences for water quantities on some growth parameters but generally *A.indica* needs almost to irrigate by high amount of water (Q2) to expand its total height comparing with a lowest amount of water (Q5), however; *G.Arborea* needs to irrigate by low (Q5) water quantity to enhance and improve its height. Finally; using models equations help to predict a total height of tree using three factors solar radiation energy, water quantities and root collar parameter (RCD).

Acknowledgements

The author wishes to acknowledge the project “Establishment of plantation forests and development of sustainable forestry in desert lands of Egypt using sewage water education and research project” which funded by the German Academic Exchange Service or (DAAD) and their team work participant from (TUM ‘Technische Universität München’- Ain shames university- Alexandria University- sector of plantation ministry of agricultural and land reclamation’ for excellent encouragement, technical and recommendations.

References.

1. Alder, D. 1980. Estimation des volumes et accroissement des peuplements forestiers – Vol. 2. Étude et prévision de la production. Études FAO: forêts No. 22/2. Rome, FAO. 194 pp.

2. Alex O. Obara, Martina G. Höft and Robert Höft (2004); Neem, Azadirachta indica A. Juss. (Meliaceae), and Its Potential for Sustainable Woodcarving in Kenya, Economic Botany Vol. 58, No. 1 (Spring, 2004), pp. 98-111.
3. Andrea Rojas, Leonardo Moreno, Luz Marina Melgarejo, and Miguel A. Rodríguez M. (2012) Physiological response of gmelina (Gmelina arborea Roxb.) to hydric conditions of the colombian Caribbean, Agronomía Colombiana 30(1), 52-58, 2012.
4. Archibald, S. and Bond, W.J. 2003. Growing tall vs growing wide: tree architecture and allometry of Acacia karrooin forest, savanna, and arid environments. Oikos, 102(1): 3–14.
5. Batcheler, C.L. 1985. Note on measurement of woody plant diameter distributions. N. Z. J. Ecol. 8:129-132.
6. CSSRI. 1989. Sewage water: utilization through forestry. Karnal, India, Central Soil Salinity Research Institute.
7. Dhôte, J.F. 1996. A model of even-aged beech stands productivity with process-based interpretations. Ann. Sci. For., 53(1): 1–20.
8. Dietze, M.C., Wolosin, M.S. and Clark, J.S. 2008.Capturing diversity and interspecific variability in allometries: A hierarchical approach. For. Ecol. Manag., 256(11): 1939–1948.
9. FAO AQUASTAT. FAO's Information System on Water and Agriculture: Climate Information tool. AQUASTAT Climate characteristics. http://www.fao.org/nr/water/aquastat/main/ (August 2015).
10. FAO (56). Crop evapotranspiration - Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. Richard G. Allen, Luis S. Pereira, Dirk Raes and Martin Smith. Rome (1988). Pp 133-134.
11. Gindaba, J., A. Rozanov, and L. Negash. 2004. Response of seedlings of two Eucalyptus and three deciduous tree species from Ethiopia to severe water stress. For. Ecol. Manage. 201, 119-129.
12. Grattan, SR; Bowers, W; Dong, A; Snyder, RL; Carroll, JJ and William G. (1998). New crop coefficients estimate water use of vegetables; row crops. California Agriculture 52(1):16-20.
13. King, D.A. 1996. Allometry and life history of tropical trees. J. Trop. Ecol., 12: 25–44.
14. Kozlowski, T.T. and S.G. Pallardy. 1997. Physiology of woody plants. 2nd ed. Academic Press, San Diego, CA
15. Martínez, T., J. Vargas, A. Muñoz, and J. López. 2002. Respuesta al déficit hídrico en Pinusleiophylla: consumo de agua y crecimiento en plántulas de diferentespoblaciones. Agrociencia 36, 365-376.
16. Meeuwig, R O. and J.D. Budy.1981. Point and line-intersect Sampling in pinyon-juniper woodlands USDA For. Serv. Gen. Tech. Rep. INT-104, 38P.
17. Murthy, V.R.K.(2003) Crop growth modelling and its Applications in agricultural Meteorology-Satellite Remote Sensing and GIS Applications in Agricultural Meteorology- Proceedings of a Training Workshop held 7-11 July 2003 in Dehra Dun, India 2003:pp.235-261.
18. Noad T and Birnie A. 1989. Trees of Kenya. General Printers, Nairobi.
19. Rawlins, S.L. 1977. Uniform irrigation with a low-head bubbler system. Agric. and Water Manage, 1: 167-178.
20. Skovsgaard, J.P. and Vanclay, J.K. 2008. Forest site productivity: a review of the evolution of dendrometric concepts for even-aged stands. Forestry, 81(1): 13–31.
21. Walter h. Gardner.1988. Water Movement in Soils. Factsheet- Washington State University: 23-27 (on the web at (www.oremax.com/pdfs/resources/water_movement_in_soil.pdf.

1/18/2016