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RESEARCH ARTICLE

Analysis of Several Discharges – Durations- Drip Line Placements Under Mango Trees "Tommy Atkins" (Magnifera Indica L.) In Zabid Valley, Tihama- Yemen.

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Abstract

The wetted volume of root area is one of the most important parameters for irrigation efficiency in the drip irrigation. Three durations (short – moderate-long duration) were compared with supplied 40, 60 and 80 L respectively. Three discharges (8, 16, and 32 l/h) were used and four treatments were tested for each discharge: one dripper, two drippers, four drippers with a looping of 20 cm and 40 cm around the trunk. The case of discharge 8 L/h with irrigation duration (10 h) in the treatment four drippers with a looping 40 cm around the trunk was superior and given the best percentage of root wetted area, 100% of the effective root area, as well as, an average volumetric water content and a coefficient of uniformity were 26% and 87%, respectively. Also, the saved water was 65.5 % compared to surface irrigation.

Introduction:-

In arid and semi-arid areas, water resources are limited and scarce (e.g. Yemen), the selection of the appropriate irrigation method in term of water use efficiency and yield is very important. Drip irrigation offers unique agronomical, agrotechnical, and economical advantages for the efficient use of water. In Yemen 90 % of the total water consumed for irrigation and 99 % of agricultural crops are irrigated by traditional methods (flooding) with very high water losses. Hence, Irrigation efficiency is very low 40- 45 %, the modern irrigation methods (sprinkler, bubbler and drip irrigation) are used in only 1% of the total irrigated area (FAO, 2012).

Mango tree in Yemen has spread widely as a result of the economic profits and food as well as their adaptation to the current environmental conditions in Yemen. The mango crop cultivated area occupies about 25842 hectares and represents 38% of the total area of fruit cultivation. A mango production by Yemen about 383107 (Mt), in the Tihama plain where was conducted, our experimentation, an area of the mango crop occupies about 10936 hectares which represents 11 % of the total irrigated area (MAI, 2013). The mango tree in The mango crop area reaches about 25842 hectares and occupies 38% of the total area of fruit cultivation. In The mango farms are irrigated by flooding irrigation. Surface irrigation is the main practice in the mango farms, the amount of water applied to mango trees is about 25563 m^3 / ha / season. Bithell et al. (2011) estimated the total water use of mango crops to be 204.4 mm (2044m^3). As for the net mango water use, the average daily rates ranged from 0.114m^3 /tree/day for drip irrigation and 0.172 m3/tree/day for surface irrigation (Al-Amoud et al., 2015).

Trickle irrigation is one of the most efficient methods and the system usually makes use of saving water supply in order to apply the precise amount of water to the root zone. It is planned to deliver frequent light applications of water to wet only portions of the soil (Al-Qinna and Abu-Awwad, 2001).

Advantages and characteristics of the drip irrigation system were analyzed by many researchers (Dagdelen et al., 2009; Fernandez-Galvez, 2006; Simonds, 2006; Phene, 1991; Phene et al., 1992), the drip irrigation offers a great potential to improve water management by improving crop yield and quality using less water, and by localizing fertilizer and chemical. Matter. (2007), observed that the average yield of mango under surface drip irrigation and sub- drip irrigation increased by 15 % and 26 % respectively in comparison to surface irrigation (furrow). Moreover, total water consumed under drip irrigation was 54.22% less than that of furrow irrigation methods (Soomro et al., 2015). Tagar et al, (2012) found that Drip irrigation method saved 56.4% of water and gave 22% more yield as compared to that of furrow irrigation method. Ibragimov et al, (2007) reported that yield was increased by 18-42% and water use efficiency increased by 35 to 103% under drip irrigation system. Trickle (drip) irrigation used 60% less water than surface irrigation whereas production was respectively 17.755 Ton /ha compared 10.715 Ton /ha of surface (Thabet, 2013). In drip irrigation takes wetted volume of the root area area of great importance, (Mirjat et al, 2011) observed that the decrease wetted area of the root area of mango trees causes a decrease of the productivity. The size of the wetted soil volume under emitters is an important field characteristic in trickle irrigation system design (Revol etal.,1991).The wetted volume under drip irrigation system was the subject of discussion of many studies (keller and karmeli, 1974; Keller and blienser , 1990; Al-Qinna et al., 2001; Hamammi et al., 2002; El-Hafedh et al., 2001; Alizadeh, 2003; Moshé, 2007; Hoori and Alizadeh, 2007 ; Azevedo et al., 2011; Harby, 2014; Thabet, 2013; Molavi et al., 2012; Maysoon, 2014; Neshat and Nasiri, 2012), These studies showed that the volume of the wetted area is influenced by many factors, include soil physical properties, soil initial humidity, as well as emitter discharge rate , durationof application , crop root characteristics and evapotranspiration. For the wetted area, most engineers agree on a minimum of 33% and maximum of 67 % (FAO, 2002). Keller and Blienser (1990) reported a percentage wetted ranged between 50-60 % for a low rainfall area and 40% in a high rainfall area. Irrigation management depends on some parameters, such frequency, irrigation duration, dripper’s discharge and spacing and the placement of drip tubing (Skagge et al., 2004). Thorburn et al, (2003) they concluded that among the distance of drip irrigation, the ratio of flow, the wet characteristics of soil and period irrigation should be a harmony in the drip irrigation for improvement of efficiency of consumption water and mineral material. There are numbers of configuration designed to increase the percentage wetted area and still be economical (double lateral, pigtail, zig-zag, looping and spaghetti tubes) (Merkley and Allen, 2004). The wetted soil volume under emitters is an important field characteristic in trickle irrigation system design (Revol et al., 1991). The boundaries of the wetted soil volume where the volume of wetted soil that was above the field capacity of soil (Gençoglan and Yazar, 1998). The restricted volume of wetted soil under trickle irrigation and the depth-width dimensions of this volume are of considerable practical importance. The volume of the wetted soil represents the amount of soil water stored in the root zone, its depth dimension should coincide with the depth of the root system while its width dimension should be related to the spacing between emitters and lines, thus, the volume and geometry of the wetted soil under an emitter should become an objective rather than an end result of the design process (Zu, 1996).

The knowledge of root distribution of agricultural crops enables accurate decision-making for a rational and sustainable use of cultural practice such as soil and water management and crop fertilization. The distribution of roots of “Tommy Atkins” mango evaluated by Marcelo al., (2014) who have observed that the highest density of the root system is concentrated from 0.50 to 1.50 m distance from the trunk and 0.20 to 0.9 m depth in the soil. Experimentation was conducted in an 11 and 12 years age orchard in a sandy soil under drip irrigation. Also, Choudhury et al., (1992) observed that most of roots were found at distances of 0.3 m to 1.6 m from the trunk and the depths from 0.3 m to 0.9 m.

There are numbers of configuration designed to increase the percentage wetted area and still be economical (double lateral, pigtail, zig-zag, looping and spaghetti tubes) (Merkley and Allen, 2004). For the best particles of drip irrigation leading to high efficiency of mango irrigation.

The objective of this paper was determined the optimal irrigation duration under drip irrigation with a better discharge and the design of the drip line around trees. In Tihama, research in the field of drip irrigation has not been studied extensively. Our research will be a good start of the spread of the drip irrigation techniques in Yemen.

Materials and methods:-

Experimental site:-

The experimental field was conducted during September, October, November and December 2014 in a farm (latitude 14° 13’ 10.71”N, longitude; 43° 21’ 33.01”E and an altitude of 127 m), located in Zabid valley, in the southern part of the Tihama plain in the west of Yemen. It’s an arid area characterized by an annual average rainfall of 100 mm. In winter, the average minimum and maximum temperatures are respectively 20 °C and 29.8 °C, while in the summer; the average values are 38.8 °C and 45 °C. The data were recorded on the Jerbah Station, nearby the site. The soil particle size distribution was 75 % sand, 7.2% silt and 17.8 % clay (sandy loam). The bulk density and porosity were $1.5g/m^3$ and 43%, respectively. The volumetric water content at field capacity and at permanent wilting point where 21% and 9% respectively. The saturated hydraulic conductivity is about 9 cm/h. Water for irrigation was pumped from the well and salinity (EC) was $0.92dsm^{-1}$.

Irrigation treatments:-

A drip irrigation system was designed and installed on the twelve trees in the farm, four trees for each discharge the trees were 10 years old and spacing 6 × 6 m. Four treatments were tested, one dripper next to the trunk tree (1d), two drippers on both sides of the trunk tree (2d), four drippers around the trunk with a looping spacing of 20 cm (4d-20cm), four drippers around the trunk with a looping spacing of 40 cm (4d-40 cm) and supplied water was 80, 60 and 40 liters for each discharge and treatment (Table 1) and (Fig.1 Three irrigation durations were adopted and the same amount of water was supplied for each irrigation duration.

Long irrigation duration, 10 hours for the discharge 8 L/h, 5 hours of the discharge 16 L/h and 2.5 hours for the discharge 32 L/h, moderate irrigation duration 7.5 hours for discharge 8L/h, 3.75 hours of the discharge 16 L/h and 1.9 hours of the discharge 32 L/h and short irrigation duration, 5 hours of the discharge 8L/h, 2.5 hours of the discharge 16 L/h and 1.25 hours for the discharge 32 L/h.

Table 1:- Amounts of water, irrigation durations, number of drippers and different discharges

Amount of water (L)	Irrigation duration (h)	Number of drippers			
		One dripper (1d)	Two drippers (2d)	Four drippers with a loop 20 cm (4d-40cm)	Four drippers with a loop 40 cm (4d-40cm)
		Discharge (L/h)			
40	5	8	4 L/h per dripper	2 L/h per dripper	2 L/h per dripper
	2.5	16	8 L/h per dripper	4 L/h per dripper	4 L/h per dripper
	1.25	32	16 L/h per dripper	8 L/h per dripper	8 L/h per dripper
60	7.5	8	4 L/h per dripper	2 L/h per dripper	2 L/h per dripper
	3.75	16	8 L/h per dripper	4 L/h per dripper	4 L/h per dripper
	1.9	32	16 L/h per dripper	8 L/h per dripper	8 L/h per dripper
80	10	8	4 L/h per dripper	2 L/h per dripper	2 L/h per dripper
	5	16	8 L/h per dripper	4 L/h per dripper	4 L/h per dripper
	2.5	32	16 L/h per dripper	8 L/h per dripper	8 L/h per dripper

Soil samples were taken before the beginning of the irrigation and at the end of each irrigation durations. Soil samples were collected from four successive layers (0-25, 25-50, 50-75 and 75-100 cm) with distance, 0, 25, 50, 75 and 100 cm from the drippers.

Crop water requirement (etc):-

Crop water requirement model 8.0 was used to calculate reference daily evapotranspiration (ET_0), it varies from 4.19 to 5.85 mm/day, the average was 4.9 mm/day. The crop coefficient is equal to 0.9 during January and February and to 0.85 during March to December. ET_C Is calculated by this formula:

$$ET_C = ET_0 \times K_C \times K_r \quad (1)$$

K_C = crop coefficient;

K_r Is ground cover reduction factor is estimated as $2 \times \frac{GC}{100}$.

In our case, The canopy diameter (R) of the tree is about 3.5 m The daily water value supplied by the tree is an average calculated using Eq. (1). With ET_0= 4.9, K_C= 0. 85 and K_r= 0. 54, trees spacing 6× 6 m. A value of 80 L/day was used in our application

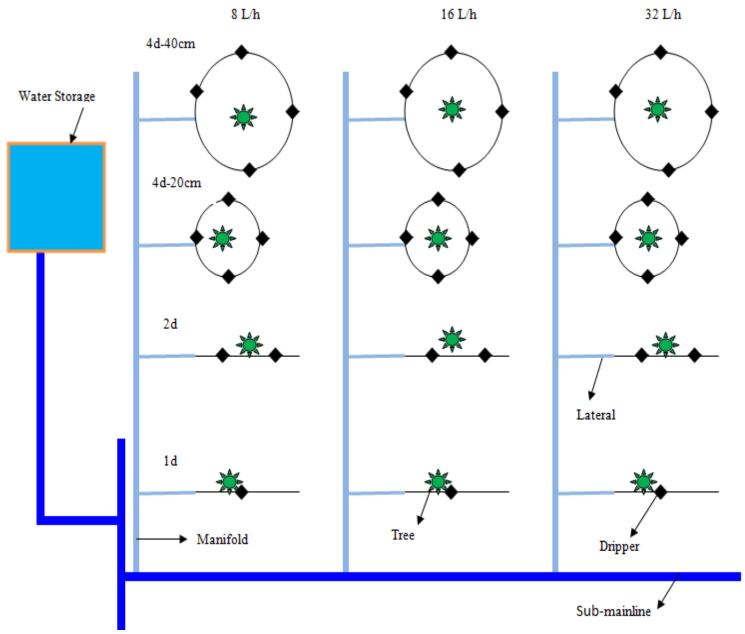

FIG. 1. Field drip irrigation layout.

Three criteria were used; average volumetric water content ($\bar{\theta}$), coefficient of uniformity (CU %) and the percentage wetted volume of the effective root area (V_W).

Average volumetric water content ($\bar{\theta}$)

$$\bar{\Theta} = \frac{\sum_{i=1}^{N} \Theta_i}{N \times 4} \quad (2)$$

Where θ_i = volumetric water content measured, n = the number of the samples for each layer

Coefficient of uniformity (CU%):-

Coefficient of uniformity (CU) is an important objective for irrigation. The equation used to evaluate the uniformity of water redistribution below the soil surface was Christiansen's coefficient of uniformity (Cu). This equation is the most widely and accepted criterion used to define uniformity (Christiansen, (1941); Ould Mohamed El-Hafedh et al, (2001); Zoldoske et al, 1994).

$$CU\,\% = 100 \times \left[1 - \frac{\sum|\theta_i - \bar{\theta}|}{n \times \bar{\theta}}\right] \quad (3)$$

Percentage wetted volume of the root area (P_w%):-

With the aim to evaluate the irrigation efficiency, The wetted soil volume of root area (V_W) and the percentage of the wetted volume of the root area (V_R) were calculated. Assuming that the wetted soil volume under a point source is a cylindrical shape in the root area (Peries et al., 2007; Thabet and Zayani, 2008). Thus, can be estimate of V_w as follows:

$$V_W = A_W \times d \quad (4)$$

Where A_W = the surface wetted area at the level zero, it was made by following a formula:

$$A_W = \pi \times \frac{D^2}{4} \quad (5)$$

Where D= diameter of the wetted area, d = an average depth of the wetted front in the root area measured at the points 0, 25, 50, 75 and 100 cm from the drippers.

Most of the active roots of the mango are calculated from the following formula (Santose et al., 2014):

$$V_R = 1.5 \times 1.5 \times 3.14 \times 0.9 = 6.4\ m^3 \sim 7 m^3$$

Where, root depth of 0.9 m and the distance roots from the trunk 1.5 m (Santos et al., 2014). Percentages of the wetted area of the root area (P_W%) was estimated as follows:

$$P_W\,\% = \frac{V_W}{V_R} \times 100 \quad (6)$$

Where V_R = soil volume of total root area (m^3).

Average depth of application (D_W):-

Expressing the application amount as a volume is equivalent to the average depth of application gives (Keller and Karmeli, 1974):

$D_W = Y \times (FC - WP) \times Z \times Pw\%$ (7)

Y is moisture depletion for a drip irrigation equal to 20% (FAO, 2002)

Z is depth of effective roots equal to 0.9 m (Santos, 2014), Pw % is the wetted area of the effective root area.

$$D_W = 0.2 \times 120 \times 0.9 \times 100/100 = 24 \text{ mm}$$

The wetted volume of root area (7m^3) was calculated by Eq.4.

$$D_W = 24/1000 * 7 = 0.182 m^3 = 168 \text{ L each irrigation.}$$

Water saving:-

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

$$WS = \frac{W_F - W_T}{W_F} \times 100 \quad (8)$$

Where WS = Water Saving (%), W_f = Total water used in basin irrigation method (m^3/tree/day), W_t = Total water used in drip irrigation method (m^3/tree/day).

Results and discussion:-

Before the beginning of irrigation, an average volumetric water content of 17% was measured and a coefficient of uniformity of 94% was found. In this study, a soil moisture depletion of 20% was retained. This study assumes a complete coverage of total volume of the effective root area. The Iso- moisture curves were drawn by a program surfer 17, for each discharge and treatment. The wetted volume was characterized by the depth and width of wetted front (Acer et al., 2009). The width wetted was measured on the surface level from the trunk, whereas the depths wetted were the average of depth wetted at the distance 0 , 25 , 50 , 75 and 100 cm from the drippers for each discharge. They were characterized by measuring the soil moisture content by gravimetric method at the end of irrigation for each duration.

Case of short irrigation duration :-

In this case, the irrigation durations were 5 hours, 2.5 hours and 1.25 hours for the discharges 8, 16 and 32 L/h respectively. The applied water was 40 L per tree for each discharge (8, 16 and 32 L/h) and for each treatment (1d, 2d, 4d- 20 cm and 4d- 40 cm).

Wetted surface area extension and average depth of the wetted front:-

Table 2 shows that the width of the surface wetted area ranged from 75 to 100 cm, the highest value was 100 cm in the case of 8 L/h and the treatment 4d- 40 cm. The average wetted depth in the root area varied from 35 to 50 cm. The results were no significant differences in the average depth of the wetted front. It was seen in the Fig, 2-5. This result is an agreement with those (Acer et al. 2008; El-Hafed et a1.2001; Skagge et al., 2004; Molavi et al., 2012; Neshat and Nasiri, 2012).

Average volumetric water content and coefficient of uniformity:-

In the root area, the average volumetric water content varied from 19 to 22% and all the values was near the field capacity (21%), (Table 2).on the other hand The coefficient of uniformity calculated by Eq.2, they varied between 81 and 85 %.

Percentage wetted area:-

The percentage of wetted area is low (Table 2). It varies between 8 and 31%. These short durations 5 h, 2.5 h, 1.25 h in all the treatment can't be recommended. After (FAO, 2004) and (Keller and Bliesner, 1990), the wetted area must be ranged between 33- 67%.

Table 2:- Widths of the surface wetted area, depths of wetted front, volumetric water content (Θ_V) and coefficient of uniformity (CU)
Observed for different treatments and discharges

Treatment	Discharge L/h	Width of surface wetted area (cm)	Average depth of the wetted front (cm)	$\bar{\theta}$ (%)	CU (%)	V_W (m3)	P_w %
1d	8	75	50	22	85	0.9	17
	16	75	35	19	85	0.6	10
	32	75	35	20	84	0.6	10
2d	8	75	55	22	85	1	17
	16	75	35	20	81	0.6	10
	32	75	40	21	84	07	12
4d-20cm	8	90	50	22	86	1	17
	16	90	35	21	85	1	17
	32	90	35	20	84	1	17
4d-40cm	8	95	50	22	83	1.4	23
	16	90	45	21	84	1	17
	32	90	40	20	86	1	17

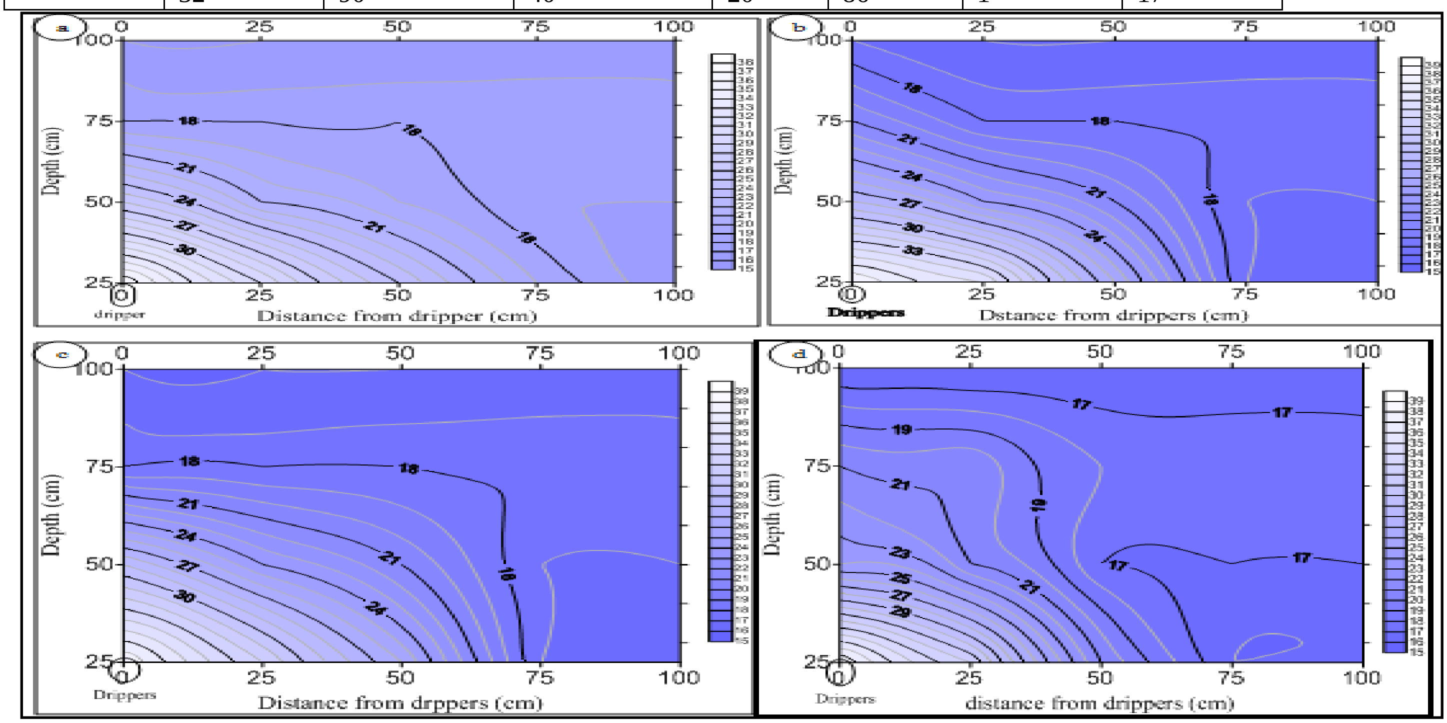

FIG .2:- iso- moisture curves in the case of the discharge 32l/h with supplied water 40 l for each treatment 1d (a), 2d (b), 4d- 20 cm (c) and 4d- 40 cm (d).

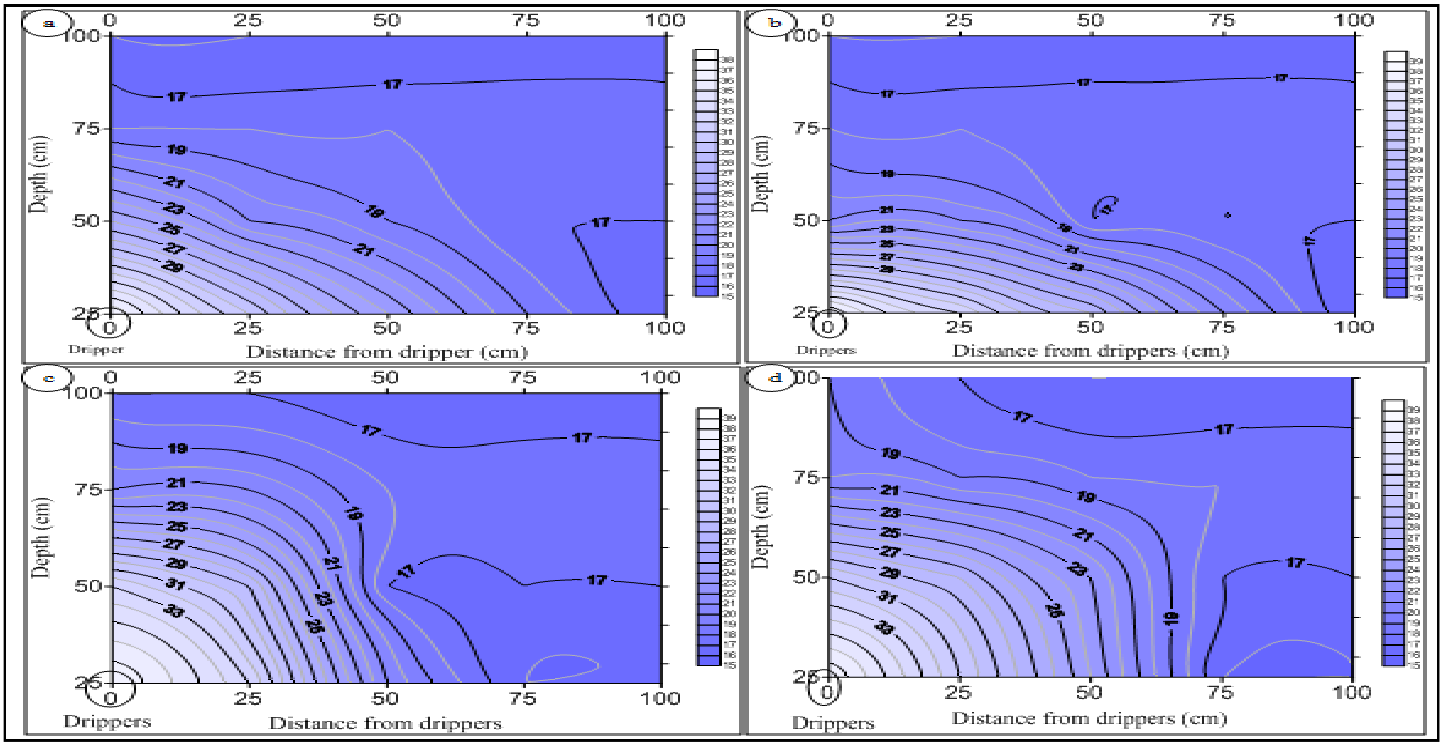

FIG .3:- Iso- moisture curves in the case of the discharge 16 l/h with supplied water 40 for each treatment 1d (a), 2d (b), 4d- 20 cm (c) and 4d- 40 cm (d).

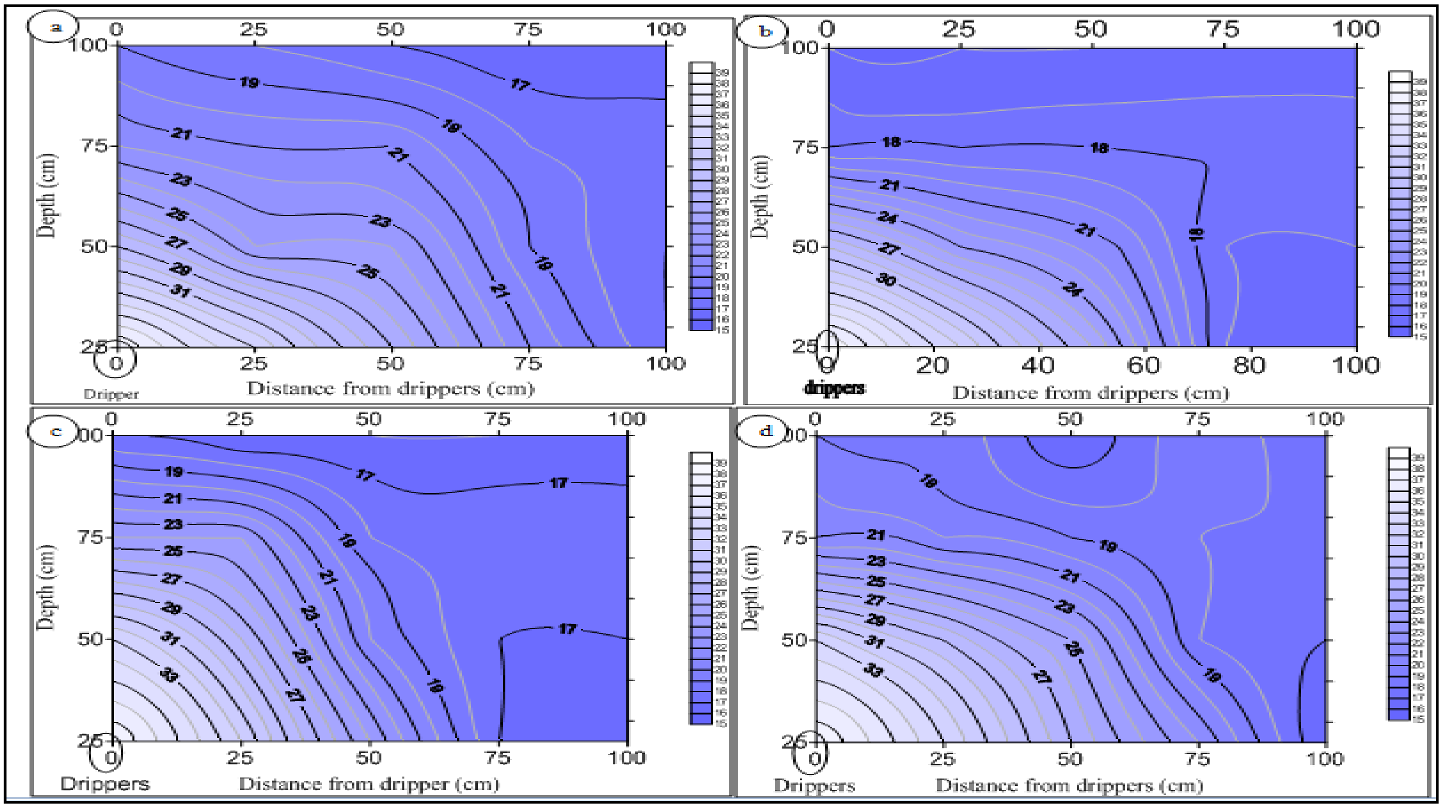

FIG .4:- Iso- moisture curves in the case of the discharge 8l/h with supplied water 40l for each treatment 1d (a), 2d (b), 4d- 20 cm (c) and 4d- 40 cm (d).

Case of moderate irrigation duration:-
The irrigation durations tested were 7.5 , 3.75 and 1.9 hours corresponding respectively to 8, 16 and 32 L/h. An amount of 40 L of water was supplied per tree.

Widths of surface wetted area and average depth of the wetted front:-
Table 3 shows that the width of the surface wetted area ranged from 75 to 115 cm, the highest values were 115 cm in the treatment 4d-40 cm in the discharges 8, 16 and 32L/h. The wetted front depth in the root area ranged from 40-75 the lowest value was 40 cm. The most observations illustrate that an average depth of the wetted front were approximately in all the discharges and treatments. Whereas, The widths of the surface wetted area were a superiority in the treatments 4d- 40 cm and 4d -20 cm (looping), it was between 95- 115 cm (Table 3) This value is very important. This result was an agreement with Merkey and Allen. (2004) have recommended that, a looping can be increased of wetted area in the root area. Here too, This result is an agreement with those (Acer et al. 2008; El-Hafed et a1.2001; Skagge et al., 2004; Molavi et al., 2012; Neshat and Nasiri, 2012).

Average of volumetric water content and coefficient of uniformity:-
The average volumetric water content in the root area varied from 21 to 24%, little more than the field capacity (21%) (Table 3). Also, The coefficient of uniformity varied between 80 and 86%. The values of average volumetric water content were increased in this case compared the short duration in the above (Table 2 and 3). The values are increased near the drippers and it decreases when moving away from the droppers laterally and vertically, (Fig.5-7).

Table 3:- Widths of the surface wetted area, depths of wetted front, volumetric water content (θ_V) and coefficient of uniformity (CU) for different treatments and discharges.

Treatment	Discharge (L/h)	Width of surface wetted area (cm)	Average depth Of the wetted front (cm)	$\bar{\theta}$ (%)	CU (%)	V_W (m3)	P_w %
1d	8	75	75	24	86	1	17
	16	75	65	22	82	1	17
	32	75	50	22	86	1	15
2d	8	75	70	24	86	1	17
	16	75	40	22	82	1	12
	32	75	50	22	82	1	15
2d-20 cm	8	95	65	23	84	2	33
	16	95	70	23	86	2	33
	32	95	50	22	85	1.4	23
4d-40cm	8	115	75	23	85	3	50
	16	115	75	23	85	3	50
	32	115	60	21	80	2	33

Percentage wetted area:-

Table 3 reveals that the percentage of the wetted area varied between 12 to 50%. The highest value was 50% in the discharges 8 and 16 L/h in the treatment 4d-40 cm. Also, a Pw% reached 33% of the discharge 32 L/h in at the treatment 4d- 40 cm. These observations consonant with (Keller and Bliesner, 1990; FAO,2002) suggested a Pw% of 33-67% in the arid regions. On the other hand, in this case is very important in the application of the regulated deficit irrigation, this system uses water stress (Santos et al. 2013; Santos et al,2014 mcCarthy, 2000). Was observed that the percentages wetted (Pw%) is effected by a low discharge and the designed drip line (looping).

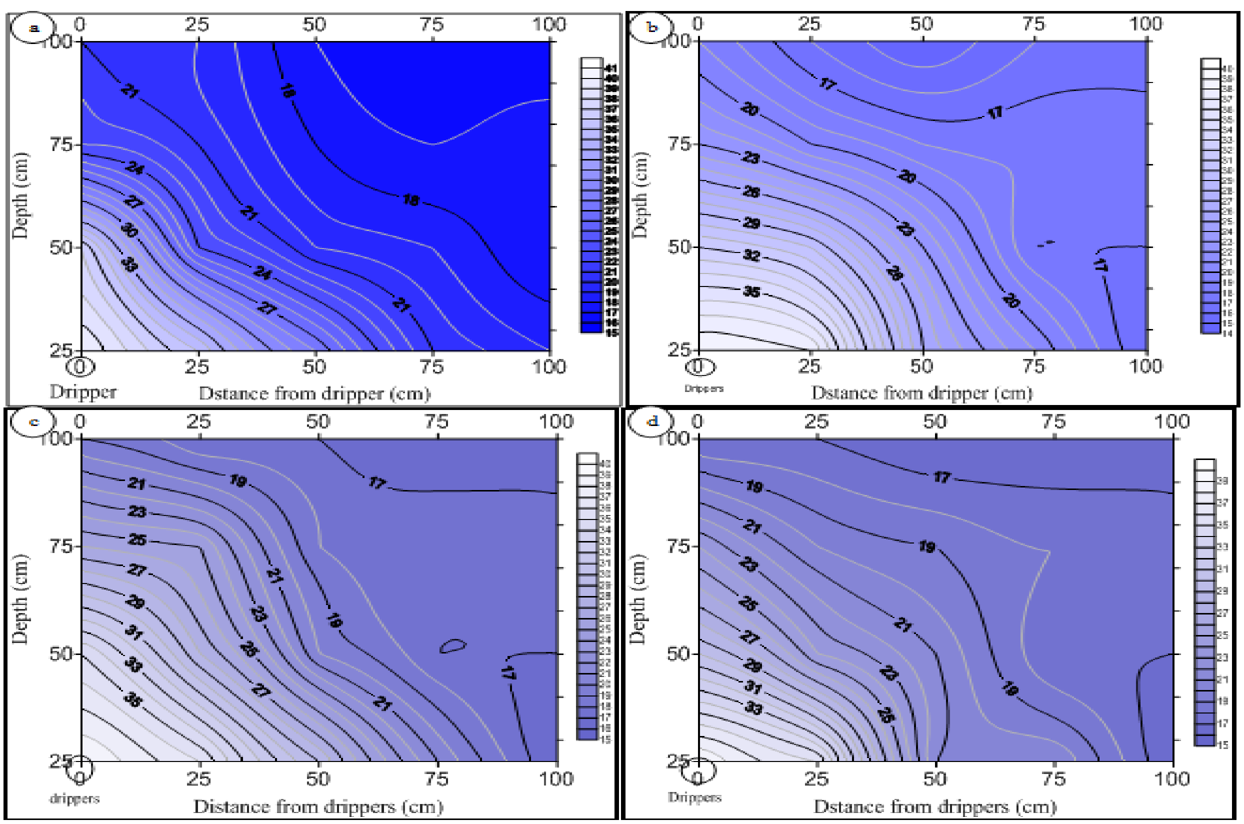

FIG .5:- Iso- moisture curves in the case of the discharge 32 l/h with supplied water 60 l for each treatment 1d (a), 2d (b), 4d- 20 cm (c) and 4d- 40 cm (d).

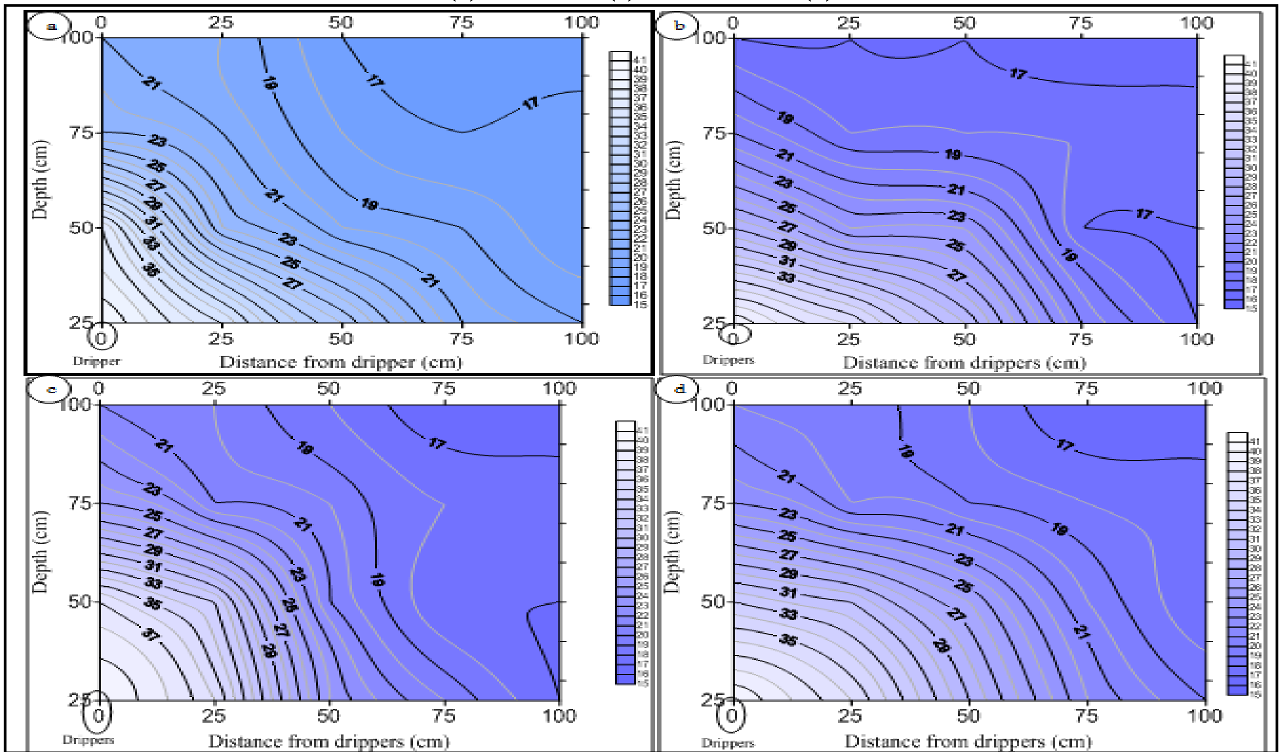

FIG .6. Iso- moisture curves in the case of the discharge 16 l/h with supplied water 60l for each treatment 1d (a), 2d (b), 4d- 20 cm (c) and 4d- 40 cm (d).

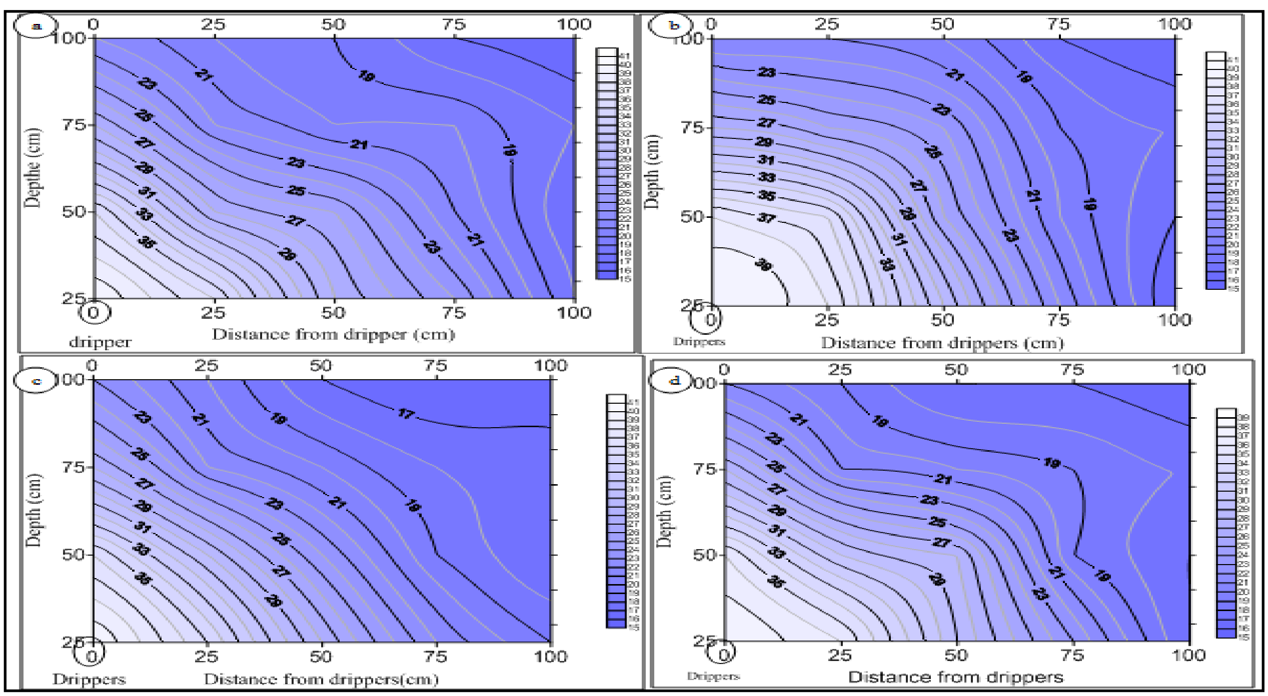

Fig .7:- Soil moisture distribution in the case of the discharge 8 L/h with supplied water 60 L for each treatment 1d (a), 2d (b), 4d- 20 cm (c) and 4d- 40 cm (d).

Case of long irrigation duration:-
In this case, the durations of irrigation adopted were 10 hours, 5 hours and 2.5 hours corresponding respectively to 8, 16 and 32 L/h, leading to the same supplied amount of water (80L).

Wetted surface area extension and average depth of the wetted front:-
Table 6 presents the width of the surface wetted area ranged from 75 to 140 cm. The highest value was 140 cm in The treatments 4d-40 cm at the discharges 8 and 16 L/h. Whereas, the value was 120 cm of the treatment 4d-20 cm at the all discharges 8, 16 and 32L/h. The wetted front depth ranged from 70 to 90 cm. There are no large differences between the values (Figs, 8-10).The highest values were observed in the case of 8 L/h, it was 90 cm, on other hand, all the values were increased compared with the cases short and moderate of irrigation (Table5,6) Here too, observed that the widths of the surface wetted area increased in the treatments 4d-20cm and 4d –cm (looping) as a result of increased water irrigation applied in the long durations compared short and moderate duration for all the discharges 8, 16 and 32L. Similary, this result was compatible with those (Neshat and Nasiri. 2012; Thabet. 2013; Acer et al. 2008; Skagge et al. 2004; Molavi et al. 2012; Neshat and Nasiri. 2012).

Average of volumetric water content and coefficient of uniformity:-
The average volumetric water content ranged from 22 to 24% and all the values were exceeded the field capacity (21%). The coefficient of uniformity (CU%) varied between 82 and 87%. The highest values were observed in the case of 8, 16 and 32 L/h with the treatment 4d-40 cm, they were between 87 and 88% (table 6). The high values of the volumetric water content are useful in this case to protect the system from unexpected disruptions, as well as facilitate regulate irrigation with water to keep the tension low in the root zone.

Percentage wetted area:-
The data in table 4 presents that a Pw% varied from 17- 100%. Observed that Pw% in the treatments 4d-20cm and 4d-40 cm varied between 50- 100 % in all the discharges 8, 16 and 32 L/h with the treatments 4d-20 cm and 4d-40 cm. We observed a superiority for the discharge 8 l/h in the treatment of 4d-40 cm, which the percentage wetted reached 100% of the effective root area. The values were very important in drip irrigation, and were compatible with (FAO, 2002; Keller and Bliesner, 1990; Markley and Allen, 2004).

Table 6:- Widths of the surface wetted area, depths of wetted front, volumetric water content (θ_V), coefficient of uniformity (CU) observed for different treatments and discharges.

Treatment	The discharge (L/h)	Width of surface wetted area (cm)	Average of the wetted front depth (cm)	$\bar{\theta}$ (%)	CU (%)	V_w (m^3)	P_W %
1d	8	100	80	26	87	2.5	42
	16	100	70	24	82	2	33
	32	100	70	24	84	2	33
2d	8	100	80	26	85	2.5	42
	16	75	70	24	84	1	17
	32	75	70	23	85	1	17
4d-20 cm	8	120	90	25	85	4	67
	16	120	80	25	85	3	60
	32	120	75	24	84	3	50
4d-40 cm	8	140	90	26	87	6	100
	16	140	80	24	87	5	83
	32	115	75	22	88	3	50

The results provided that discharges 8, 16 and 32 L/h with the treatments 4d-20 cm and 4d-40 cm (looping) were a good of drip irrigation in our experiment, The percentage wetted varied between 50-100% with superiority of 8 L/h, it reached 100%. These results are a good for drip irrigation of mango and an agreement with those of Keller and Bliesner (1990) suggested that a Pw% for arid regions ranged between 50-60 %. In case of long duration the treatment 4d-40 cm in the discharge 8 L/h and water supplied of 80 L is the best, Pw% reached 100%, we can be recommended for irrigation driper for mango under the condition of valley Zabid in Yemen. The most of wetted volume that resulted formed a 'V'-shaped cross-section, this clear in the Fig, 2- 10. This result was consonant with Al-Qinna et al. (2001).

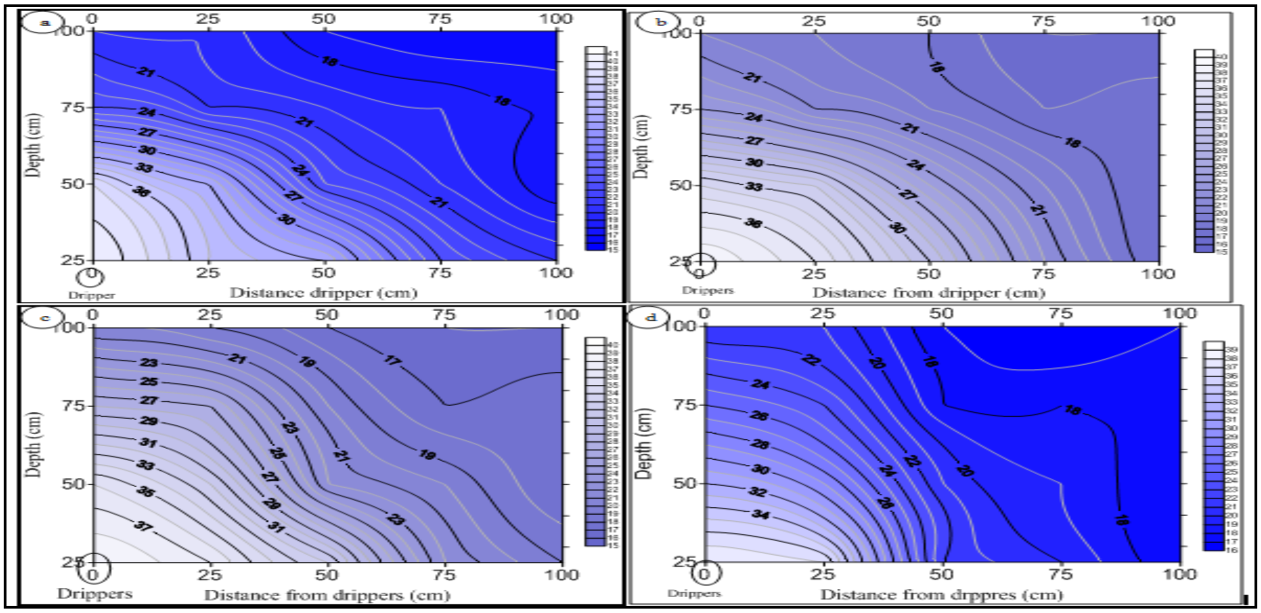

FIG .8:- Iso- moisture curves in the case of the discharge 32 l/h with supplied water 80 l for each treatment 1d (a), 2d (b), 4d- 20 cm (c) and 4d- 40 cm (d).

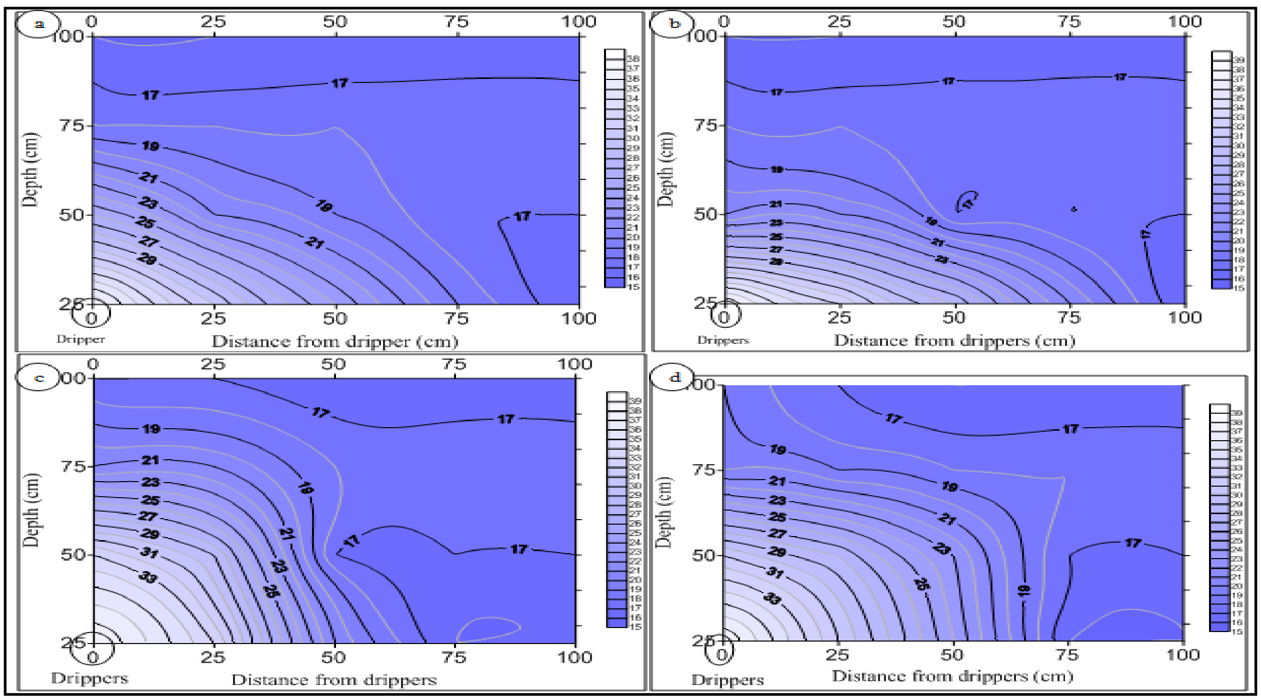

FIG.9:- Iso- moisture curves in the case of the discharge 16 l/h with supplied water 80 l for each treatment 1d (a), 2d (b), 4d- 20 cm (c) and 4d- 40 cm (d).

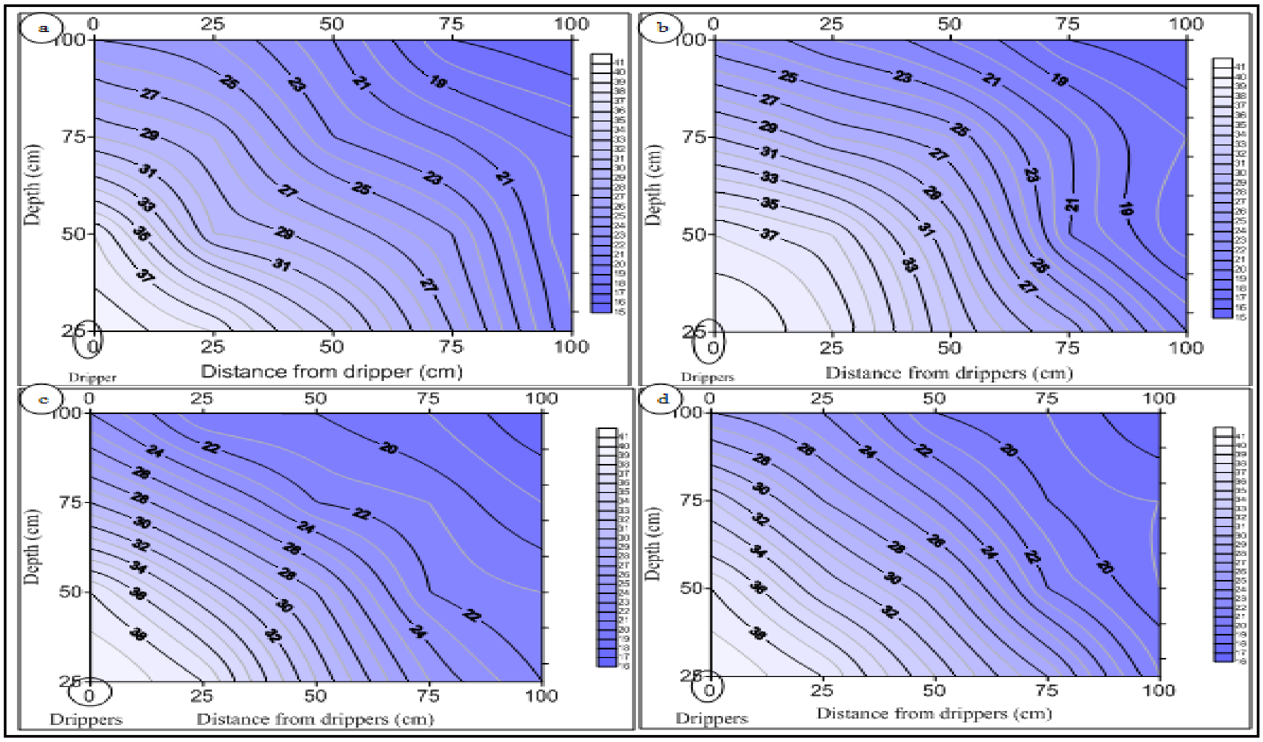

FIG. 10:- Iso- moisture curves in the case of the discharge 8l/h with supplied water 80 l for each treatment 1d (a), 2d (b), 4d- 20 cm (c) and 4d- 40 cm (d).

Statistic analysis:-

The results were statistically verified by using the analysis of variance (ANOVA). Tueky test values at the 5% probability level was applied and the program of SPSS was used.

ANOVA result shows significant differences between the treatments used. We can be observed that, there were considerable differences of a Pw% of the water supplied and drippers placement ($P < 0.05$). There were no more significant differences in the discharge. (Table 7and 8). These results compatible with (Acer et al.,2009; and Al-Qinna et al., 2001; Mirjatet al., 2006; Jiu-sheng et al., 2007).

Table 7:- ANVA results for dependent variable Pw% for a 95% confidence interval

Source of variation	Sum Of Squares	Df	Mean Squares	F	Significants
Discharge					
Within groups	1522,667	2	761,333	1,624	,212
Between groups	15468,333	33	468,737	-	-
Total	16991,000	35	-	-	-
Drippers					
Within groups	5297,000	3	1765,667	4,832	,007
Between groups	11694,000	32	365,438	-	-
Total	16991,000	35	-	-	-
Water Supplied					
Within groups	7232,167	2	3616,083	12,228	,000
Between groups	9758,833	33	295,722	-	-
Total	16991,000	35	-	-	-

Table 8:- Multiple comparisons for dependent variable Pw% for a 95% confidence interval

I	J	Mean differences (i-j)	Std. Error	Sig.	95% confidence Lower Bound	Upper Bound
Discharges						
8,00	16,00	10,33333	8,83872	,480	-11,3551	32,0217
	32,00	15,66667	8,83872	,194	-6,0217	37,3551
16,00	8,00	-10,33333	8,83872	,480	-32,0217	11,3551
	32,00	5,33333	8,83872	,819	-16,3551	27,0217
32,00	8,00	-15,66667	8,83872	,194	-37,3551	6,0217
	16,00	-5,33333	8,83872	,819	-27,0217	16,3551
Drippers						
1d	2d	4,77778	9,01157	,951	-19,6378	29,1934
	4d-20 cm	-11,66667	9,01157	,573	-36,0823	12,7489
	4d-40 cm	-26,66667*	9,01157	,028	-51,0823	-2,2511
2d	1d	-4,77778	9,01157	,951	-29,1934	19,6378
	4d-20 cm	-16,44444	9,01157	,281	-40,8600	7,9711
	4d-40 cm	-31,44444*	9,01157	,007	-55,8600	-7,0289
4d-20 cm	1d	11,66667	9,01157	,573	-12,7489	36,0823
	2d	16,44444	9,01157	,281	-7,9711	40,8600
	4d-40 cm	-15,00000	9,01157	,359	-39,4156	9,4156
4d-40 cm	1d	26,66667*	9,01157	,028	2,2511	51,0823
	2d	31,44444*	9,01157	,007	7,0289	55,8600
	4d-20 cm	15,00000	9,01157	,359	-9,4156	39,4156
Water supplied						
40,00	60,00	-9,16667	7,02047	,402	-26,3935	8,0601
	80,00	-33,58333*	7,02047	,000	-50,8101	-16,3565
60,00	40,00	9,16667	7,02047	,402	-8,0601	26,3935
	80,00	-24,41667*	7,02047	,004	-41,6435	-7,1899
80,00	40,00	33,58333*	7,02047	,000	16,3565	50,8101
	60,00	24,41667*	7,02047	,004	7,1899	41,6435

Irrigation scheduling and water saved:-

The treatment of 4d-40cm (looping) is clearly a superior. Therefor, the irrigation scheduling was conducted at this treatment for the discharges 8 and 16L/h in the duration irrigation10h and 7.5h with water applied 80 (long duration) and 60L (moderate duration) per day, respectively. The result in the Table 8 revealed that the irrigation interval was 2 and 3 days, FAO (2002) reported that the irrigation interval must be between 1-3 day in drip irrigation. The saved water, calculated by Eq.7, was 68 and 79.4 % in the treatments 4d-40 cm and 4d 20cm respectively, compared surface irrigation. This result was concordant with the many researchers (camp et al., 2001; Tagar et a1., Mirjat et al., 2006; Sharma, 2001).

Table.8:- Irrigation scheduling in the case of the discharge 8L/h and irrigation durations 10 and 7.5

Supplied water (mm)/day (a)	80	80	80	80	80	80	80	80	80	80	80	80
D_n (L) every irrigation (b)	168	182	182	182	182	182	182	182	182	182	182	182
Irrigation interval (c=(b)/(a))	2	2	2	2	2	2	2	2	2	2	2	2
Supplied water (mm)/day(c)	60	60	60	60	60	60	60	60	60	60	60	60
Irrigation interval(d=(b)/(c)	3	3	3	3	3	3	3	3	3	3	3	3

Conclusion:-

For drip irrigation, there are several parameters must be taken into account, irrigation duration, irrigation interval, discharge, lateral designing, amount of water supplied and wetted volume of effective root area. Three irrigation durations and three discharges were applied by using four treatments 1d, 2d, 4d-20 cm and 4d-40 cm. The amounts of water supplied were 40, 60, and 80 L. Width and depth of wetted front, volumetric water content, coefficient of uniformity and percentage wetted volume were evaluated. The irrigation scheduling was done. The amount of water and drippers placed around the trunk had a significant effect on the wetted volume in the root area and saved water. In the case of an amount of 80 L (duration 10 h, discharge 8 L/h) and the treatment 4d-40 cm, Pw was 100% and irrigation interval was 2 days and saved water was 68 % compared to surface irrigation.

For the durations 7.5 h and 3.75 h with the respectively discharges 8 and 16 L/h under the treatment 4d- 40 cm, even if the Pw was 50%, saved water was 79% compared to surface irrigation.

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