Middle East Journal of Agriculture Research
ISSN 2077-4605
Volume : 07 | Issue : 01 | Jan.-Mar. | 2018
Pages:117-131

Effect of Some Mulching Treatments on Water use Efficiency, Growth, Yield and Fruit Quality of Williams Banana Plant

[1]Eid T. A. and M. F. El-Kholy[2]

[1]*Soils, Water and Environmental Res. Ins., Agric. Res. Center, Giza, Egypt.*
[2]*Tropical and Subtropical Fruit Research Department, Hort. Res. Inst., Agric. Res. Cent., Giza, Egypt*

Received: 20 Nov. 2017 / Accepted: 23 Jan. 2018 / Publication date: 15 Feb. 2018

ABSTRACT

The present work was conducted at El-Kanater Horticultural Research Station during 2014/2015 and 2015/2016 growing seasons to study the effect of different irrigation regimes (irrigation at either 30 or 60 % of available soil moisture depletion) and mulching treatments; (black polyethylene plastic, rice straw; banana leaves and no mulching) on water use efficiency, vegetative growth measurements, bunch weight, yield and fruit quality of first and second ratoons of Williams banana plant. Economic studies were also done. The design of the experiment was complete randomized block design eight interaction treatments with three replicates for each treatment.

The most important results can be summarized as follows: Water consumption use (WCU) was increased in the case of frequent irrigation at 30 % of available soil moisture depletion (I_1) value which was found to be 1055 and 1032 (mm) in both growing seasons, respectively. Regarding mulching treatments, the values of the water consumption use were increased under both no mulching and rice straw mulching compared with either black plastic or banana leaves mulching.

Also, average water use efficiency (WUE) increased by plastic mulch and recorded (6.38 kg/m^3), followed by banana leaves mulch (5.70kg/m^3), and rice straw (4.14 kg/m^3) in both seasons. Plastic sheet, banana leaves and rice straw mulching generally led to increase (WUE) by 118%, 95.2% and 41.8% over the un-mulched treatment, respectively in both seasons.

Data showed that the 30 % of available water irrigation (I_1) gave the best vegetative growth, fruit yield and fruit quality under this study, while decreased duration from bunch shooting to harvest as compared with 60 % (I_2) treatment. Furthermore, the highest significant values of growth and yield were obtained when used polyethylene or banana leaves mulching, followed by straw rice compared with unmulching treatment.

Data also showed that, irrigation at 30 % of available soil moisture depletion (I_1) with covering black polyethylene and/or banana leaves mulch gave the least values of water consumptive use which were 1055 and 1032 (mm) in both seasons. And increase was attained also in pseudostem height (cm.), pseudostem circumference (cm) and number of leaves/plant. Moreover, covering with black polyethylene or banana leaves mulch resulted in significantly increase in fruiting parameters (bunch weight and yield kg/plant). In addition, most of finger characteristics were improved by using 30 % of available soil moisture depletion (I_1) than the irrigation at 60 % of available soil moisture depletion (I_2) during both 2014/2015 and 2015/2016 seasons, respectively.

In brief, it could be recommended to irrigate Williams banana plant grown on clay loam soil at 30 % of available soil moisture depletion (I_1) for saving irrigation water with best, vegetative growth, fruit yield and fruit quality under condition of this study. Mulching banana plants with black polyethylene would lower costs and increases the environment benefits compared to rice straw mulch.

Key words: Banana, irrigation regimes, mulching, vegetative growth, yield and fruit quality.

Introduction

Banana (*Musa* sp.) is an important tropical crops that can tolerate short period of water deficit (Surendar *et al*., 2013). Thus, its productivity is greatly affected. Most of the investigations have shown that plant growth rate as well as biochemical and physiological processes were directly affected proportional by availability of water in the soil (Hu and Schmidhalter, 2005). Surface

Corresponding Author: Eid T. A., Soils, Water and Environmental Res. Ins., Agric. Res. Center, Giza, Egypt.

irrigation method is most widely used all over the world (Mustafa *et al.*, 2003). Irrigation is an important for all crops, because it influences on growth and development. Availability of adequate amount of moisture at critical stages of plant growth not only optimizes the metabolic process in plant cells, but also increase the effectiveness of the mineral nutrients applied to the crop. Consequently, any degree of water stress may produce deleterious effects on growth and yield of the crop (Saif *et al.*, 2003).

As the world become greatly dependent on the production of irrigated lands, irrigated agriculture faces serious challenges that treatments its suitability. It is prudent to make efficient use of water and bring more area under achieved by introducing advanced methods of irrigation and improved water management practice (Zaman *et al.*, 2001). In this method, the major proportion of irrigation water is lost by surface evaporation, deep percolation and other losses, resulting in lower irrigation efficiencies. Moreover, there is a tendency of farmer's to apply excess water when it is available (Jain *et al*., 2000).

Among the water management practices for increasing water use efficiency (WUE) is mulching. Any material spread on the soil surface to protect it from solar radiation or evaporation is called mulch. Different types of materials like wheat straw, rice straw, plastic film, grass, wood, sand etc. are used as mulches. They moderate soil temperature and increase water infiltration during intensive rain (Khurshid *et al.,* 2006).

Evaporation from the soil surface may account as much as 50% of the total moisture lost from the soil during the growing season for soybean and corn (Shaw, 1959). In this concern, mulching with plant residues and synthetic materials is a well-established technique for increasing the profitability of many horticultural crops (Gimenez *et al*., 2002). Such effects are mainly contributed to the capacity of mulch to conserve soil moisture (Vavrina and Roka, 2000). In addition, soil temperature is very critical for biological and chemical process that control nutrient cycling (Donk Van *et al*., 2004). Also, mulching improved vegetative growth and distribution of roots and their absorption of nutrients (Verma *et al*., 2005). Moreover, using mulches helps in moisture conservation and reduction of evaporation (Sinkeviciene *et al*., 2009). Sharma *et al*., (2010) observed that mulching is very beneficial for enhancing moisture and nutrient conservation, resulting in increased productivity and improved soil conditions for cropping system.

The main objectives of this study are to investigate the effect of different available soil moisture depletion and mulching treatments with black polyethylene plastic, banana leaves, rice straw and no mulching on banana yield and its components, as well as some water-crop relations, and net return.

Materials and Methods

Field experiment was carried out at El-Kanater Horticultural Research station, Qalubiya, Governorate (Latitude: 30°.08N Longitude: 31°.15E Elevation: 16.9 m) for two successive seasons of 2014/2015 and 2015/2016 to study the effects of mulching on water consumption use, water use efficiency, some vegetative growth measurements, yield and fruit quality of Williams banana plants (*Musa cavendishii* L.) produced through tissue culture. Banana plants were cultivated 3 × 3.5 meters apart, similar in growth, free from diseases and received the same horticultural managements.

Field capacity, permanent wilting point, the available water and bulk density were determined as well as soil physical parameters and listed in Table (1). Meteorological data of the Agricultural Research Station are shown in Table (2).

Twenty four of Williams banana plants each in separate mat, were chosen and arranged in complete randomized block design (CRBD) on eight interaction treatments with three replications. In the first season, each mat yielded three suckers. Also, in the second season, each mat yielded three suckers. Irrigation started on January i.e., irrigation was done when moisture reached the relevant level to determine available soil water retained in the soil. Soil moisture was determined grave metrically on oven dry basis of soil samples taken from depths of 15 cm. up to 60 cm. Water consumption use was calculated as the differences of soil moisture content in soil samples taken before irrigation and field capacity. In both seasons, the experiment included eight treatments as follows:

Main plots (irrigation):

1- Irrigation at 30 % of available soil moisture depletion (I_1)
2- Irrigation at 60 % of available soil moisture depletion (I_2)

Sub-plots (mulching):

1- Black polyethylene plastic sheet used to cover soil surface under the plants. The polyethylene plastic sheet was 25 micron. The mulch was applied on the 1st week of March on the soil up to the end of the season.
2- Banana leaves mulch 30 cm thick was spread out on the soil surface to cover the soil completely for the same time of plastic sheets treatment.
3- Rice straw mulch 30 cm thick was spread out on the soil surface to cover the soil completely for the same time of plastic sheets treatment.
4- No soil mulching (control).

Table 1: Physical properties, soil moisture parameters and bulk density of the soil used in both seasons.

Parameter							**Value**
Particle size distribution:							
Clay							30.9 %
Silt							34.3 %
Fine sand							33.5%
Coarse sand							1.3%
Texture class							Clay loam
Soil moisture parameters and bulk density							
Depth	**Field capacity (FC)**		**Wilting point (WP)**		**Available water (AW)**		**Bulk density (BD) mg/m^3**
	% by weight	**Cm**	**% by weight**	**Cm**	**% by weight**	**Cm**	
0-15	39.8	7.28	17.9	3.28	21.9	4.00	1.22
15-30	38.3	6.89	17.7	3.19	20.6	3.70	1.20
30-45	36.4	6.93	16.3	3.11	20.1	3.82	1.27
45-60	35.7	8.03	16.6	3.74	19.1	4.29	1.50
Total		29.14		13.30		15.81	

FC: moisture at 33 kPa moisture tension. WP: moisture at 1.5 MPa moisture tension. AW = FC-WP

Table 2: Meteorological data in 2015 and 2016 seasons.

Season	**2015**						**2016**					
Month	**T. max**	**T. min**	**W.S**	**R.H**	**S.R**	**Epan**	**T. max**	**T. min**	**W.S**	**R.H**	**S.R**	**Epan**
Jan.	18.9	7.1	4.3	52	276	2.2	18.2	6.8	3.9	60	280	2.0
Feb.	20.3	7.7	4.1	48	350	2.8	23.7	9.1	3.6	51	354	2.4
Mar.	25.5	10.7	3.8	49	438	4.0	26.4	11.3	4.1	43	441	3.1
Apr.	28.5	11.7	4.3	40	516	6.1	32.8	14.2	4.2	37	519	4.6
May	34.1	16.8	3.9	36	580	6.4	34.3	17.3	4.4	35	585	5.5
Jun.	35.3	18.9	4.2	40	622	7.5	39.4	21.2	4.2	32	627	6.8
Jul.	38.2	21.1	3.7	37	615	8.0	39.9	17.9	3.9	35	613	6.9
Aug.	39.7	23.8	4.0	41	589	6.9	37.8	21.9	4.1	44	577	7.4
Sep.	37.6	22.2	3.8	45	516	6.4	35.4	20.2	3.9	47	512	4.3
Oct.	31.7	19.2	3.6	55	414	4.9	32.0	17.8	3.8	55	417	4.0
Nov.	26.0	14.4	3.6	61	319	4.4	26.5	14.0	3.6	54	280	3.3
Dec.	20.6	9.6	3.7	64	260	2.9	21.5	10.5	4.5	64	354	2.6

Where: T. max., T. min.= maximum and minimum temperatures °C; W.S= wind speed (m/ sec); R.H.= relative humidity (%); S.R= solar radiation (Mg^2/ cal / m) and Epan= evaporation by class A pan (mm/ day).[Data were obtained from the agrometeorological Unit at SWERI, ARC].

Water consumption use (CU):

Water consumptiom use or actual evapotranspiration (ETc) values were calculated for each irrigation tratment using the following formula (Israelson and Hansen, 1962).

Where: $$WCU = \sum_{i=1}^{i=4} \frac{(\theta_2 - \theta_1)}{100} X\ Bd\ X\ D$$

WCU = seasonal water consumption use (cm),
Θ_2 = soil moisture content after irrigation (on mass basis, **%),**
Θ_1 = soil moisture content before irrigation (on mass basis, %),
Bd = soil bulk density (g/cm^3),
D= depth of soil layer (15cm each), and
i = number of soil layer.

Soil moisture content was gravimetrically determined in soil samples taken from consecutive depths from 15 cm down to 60 cm. Soil samples were collected just before each irrigation, 48 hours after irrigation and at harvest time.

Calculation of crop coefficient and evapotranspiration:

Reference evapotranspiration (ETo):

Reference evapotranspiration (ETo) was calculated using the meteorological data using three formulae as cited by Doorenbos and Pruitt, (1977) and Allen *et al.,* (1998) as follows:
Formula: 1 Doorenbos - Pruitt equation:
The equation adapted the radiation formula of Makkink (1957) to predict potential evapotranspiration as follows:

ETp: bw Rs/L- 0.3

Where: ETp: Daily potential evapotranspiration (mm/day).
b: Adjustment factor based on wind and mean relative humidity.
W : Weighting factor based on temperature and elevation above sea level.
Rs: Daily total incoming solar radiation for the period of consideration (cal/cm^2/day).
L: Latent heat of vaporization of water (cal/ cm^2/ day)
Factors (b) and (w) could be obtained from the tables cited by (Doorenbos and Pruitt 1977).

Formula 2: the Pan evaporation equation:

Potential evapotranspiration (ETp) values were obtained by class A pan (Doorenbos and Priutt, 1984) and were calculated by the following equation:

$$ETp = E\ pan \times K\ pan$$

Where:
E pan = measured pan evaporation daily values, mm day^{-1}
K pan = pan coefficient. Kpan values depended on the relative humidity, wind speed and the site conditions (bare or cultivated). Kpan value of 0.75 was used at the experimental site (FAO, 1979).

Crop Coefficient (Kc):

The recommended values of Kc, according to Doorenbos and Kasam (1986) were used to estimate the ET for the banana plants under conditions of the area where the experiment was done. The formula is as follows:

Kc = Etc / ETo

Where: Kc = Crop coefficient.
ETc = The measured (actual) evapotranspition of a considered period (mm/day)
Eto = reference evapotranspiration (mm/day) referring to the same period, calculated as average value of four formulas

Water use efficiency (WUE)

Water use efficiency (WUE) is used to describe the relationship between production and the amount of water used. W.U.E. was expressed as the amount of banana fruits in Kg that could be produced from one cubic meter of water. It was determined according to the following equation (Vites, 1965):

$$\text{W.U.E} = \frac{\text{Fruits yield (kg)/fed}}{\text{Seasonal ET (m}^{3\,/}\text{ water consumed)/fed}}$$

Soil physical analysis:

Particle size distribution was conducted using the pipette method and bulk density according to Klute (1986). Soil moisture constant was determined using the pressure membrane apparatus, considering the saturation percent (SP) at KPa tension. Field capacity (FC) and wilting point (WP) at 0.33 and 15 bar, respectively. Available water is the difference between FC and WP (Stackman, 1966).

Vegetative growth:

Morphological measurements were done at bunch shooting stage via the following parameters: Pseudostem height (cm.), pseudostem circumference (cm) and number of leaves/plant.
Flowering: 1) Time to flowering: The period from sucker emergence to bunch shooting (in days) date was calculated in the tested seasons.
2) Time to harvesting: the period from bunch shooting to the date of harvesting (in days) was calculated in the two seasons.

Yield, bunch weight and finger properties:

At time of harvesting, bunch weight in Kg, finger weight (g), finger length and diameter in cm were measured and recorded.

Statistical analysis:

The experimental data were tabulated and statistically analyzed according to Snedecor and Cochran (1980) and the differences between the means of various treatments were compared according to Duncan's Multiple Range Test at 0.5 level of probability (Duncan, 1955).

Results and Discussion

1. Soil-water relations:

Topics discussed here include consumption use of water (CU) measured actually during the season (considered as actual evapotranspiration, i.e. actual ET) as affected by the different treatments. Also presented and discussed the calculated crop coefficient in comparison to actual and calculated ET, as well as water use efficiency (WUE).

1.1. Seasonal water consumption use:

Evapotranspiration is the combination of two processes; evaporation and transpiration. Evaporation is the direct vaporization of water from the soil surface and/or from plant surfaces. Transpiration is the flow of water vapor from the interior of the plant to the atmosphere (Jones *et al*., 1984).

Seasonal water consumption use (i.e. WCU or ETa.) by banana plants was decreased as water stress increased, in both seasons (Table, 3). The main effect of irrigation treatments shows that I_1 gave the highest water consumption use followed by I_2. Mean values were 1055 and 840.9 mm. in the first season and 1032 and 826.2 mm. in the second one for I_1 and I_2, respectively. Such result might be reasonable, since more frequent irrigation period provide high evaporation opportunity from the relatively wet rather than dry soil surface (Levitt *et al*., 1995 and Devit *et al*., 1994)

The actual evapotranspiration (ETa) values under soil mulching are lower than the ETa values under un-mulching soil. Plastic mulch treatments recorded the lowest values of ETa followed by banana leaves then rice straw mulch treatments as compared to the un-mulched treatments. Seasonal water consumption use values were as follows: un-mulching gave the highest water consumption use of 1187 mm followed by rice straw which gave 988.3 mm, then banana leaves which gave 838.9 mm and the lowest was by plastic which gave 787.5 mm in the first season and 1163, 969.4, 833.6 and 749.8 mm in the second growing season, respectively.

The differences were obtained between un-mulched soil and mulched soil with plastic, banana leaves and rice straw. Plastic, banana leaves and rice straw reduce ETa by 33.1, 28.7 and 16.0 %, in the first season and 35.7, 29.4 and 16.8 % in the second one, respectively comparing with un-mulched soil. These results are supported by the observation of Khalifa (1994), El-Henawy (2006) and Mikhael (2007). They mentioned that, monthly and seasonal water consumption uses of citrus were decreased as affected by different type of mulching.

Table 3: Seasonal water consumption use (mm.) for banana plant as affected by soil moisture regimes and different mulching treatments.

Depletion available water (%)	Black polyethylene plastic	Banana leaves	Rice straw	Unmulched	Mean
	First sason 2014/2015				
I_1	864.9	930.5	1098	1327	**1055**
I_2	692.2	747.4	878.5	1046	**840.9**
Mean	**778.5**	**838.9**	**988.3**	**1187**	
	Second season 2016/2016				
I_1	831.4	926.1	1077	1292	**1032**
I_2	668.2	741.1	861.9	1034	**826.2**
Mean	**749.8**	**833.6**	**969.4**	**1163**	

I_1: Irrigation when 30 % of available soil moisture was depleted, I_2: Irrigation when 60 % of available soil moisture was depleted.

1.1.1 . Monthly water consumption use:

The results regarding monthly water consumption use I_1 with black polyethylene plastic, banana leaves, rice straw and no mulching only. Regarding the effect of irrigation and mulching treatments and their interaction on monthly and total water consumptive use (WCU) for banana plants, the data of both seasons illustrated in Fig. 1 showed that, monthly values of water consumptive use, (mm) were gradually increased starting from end of March and reached the maximum values during July and August, then declined from October to December. This might be due to the increase in growth during summer months, temperature increment or both. This trend was found to be true under all mulching treatments. The data also show that, monthly values of water consumptive used of banana plants under soil mulching with either black P.E. or leaves of banana were the lowest. Meanwhile, the highest values were observed under unmulched bare soil. Weagand (1962) pointed out that, the drying rate of bare soil is positively related to the water content and relatively related to lime, and that a drying front advances into the soil linearly. Ibrahim (1981) concluded that the increase in evapotranspiration by maintaining soil moisture at a high level is attributed to excess available water in the root zone.

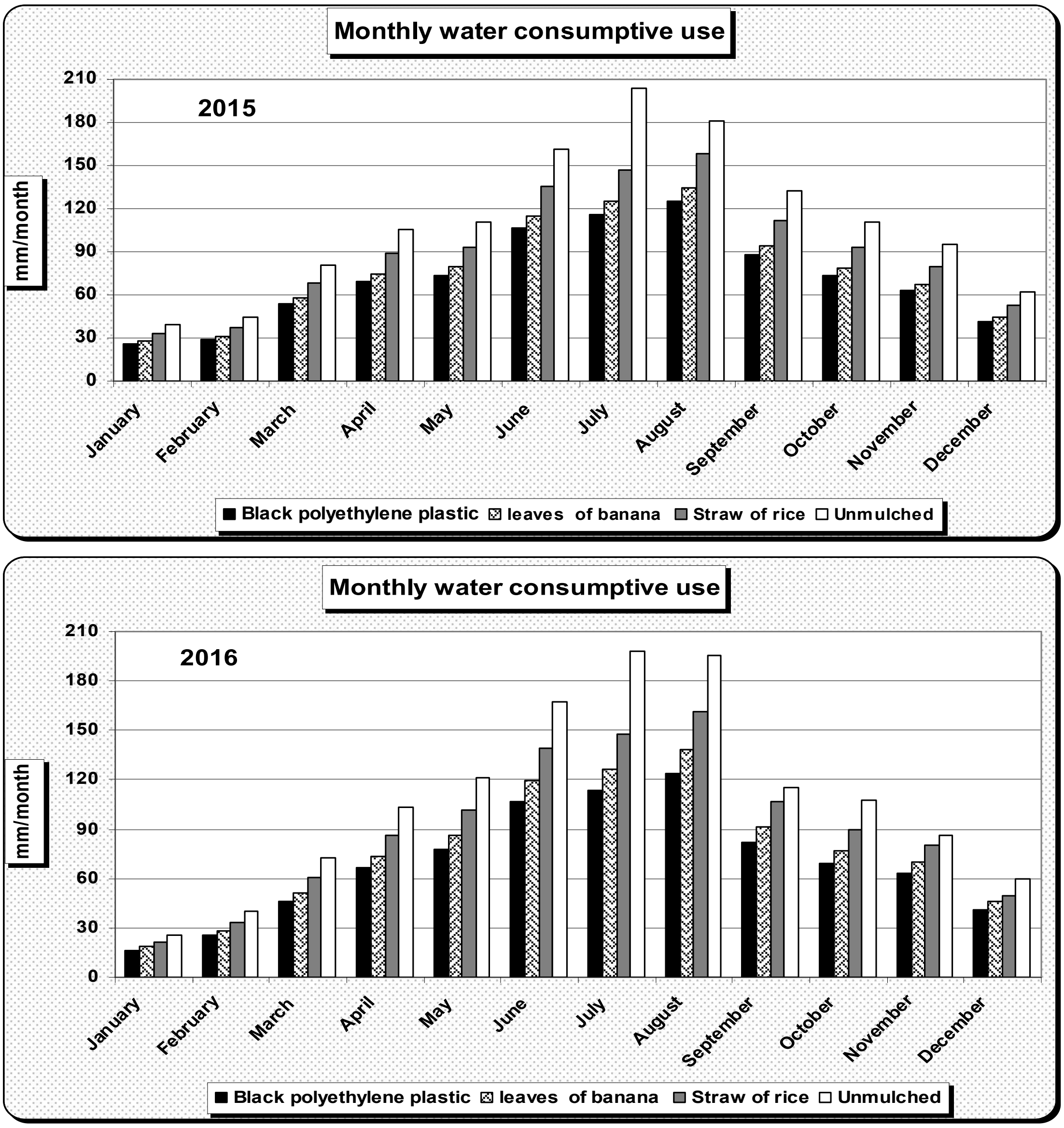

Fig. 1: Monthly water consumptive use mm/month for banana plants as affected by different mulching treatments during 2015 and 2016 seasons.

1.2. Reference evapotranspiration (ETo):

The major parameters required to calculate the ETo are the climatological data, length of growth period of the cultivated crops and surface properties. Data illustrated in Table (4) show that the values of reference evapotranspiration (ETo) which were calculated according to Doorenbos-Pruitt and Pan evaporation equations reached the maximum in July and August while January reflected the minimum value in both 2015 and 2016 seasons. This trend is due to the variation in cultivate and climate during the two seasons of study. The ETo values calculated by Pan evaporation method were lower than those values obtained by the Doorenbos- Pruitt method during the growing months in both seasons.

Table 4: Monthly ETo and ETa mm/month for banana plants as affected by the different treatments according to the studied equations during 2015 and 2016 seasons.

ETa mm/ month Actual water consumption use					ETo mm/ month	
First season 2015						
Months	**Black polyethylene plastic**	**leaves of banana**	**Rice straw**	**Unmulched**	**Doorenbos-Pruitt**	**Epan**
January	25.9	27.8	32.9	39.1	62.6	51.8
February	29.3	31.4	37.0	44.0	76.2	58.8
March	53.6	57.6	67.9	80.8	119.4	91.8
April	69.8	75.0	88.5	105.4	120.0	130.5
May	73.6	79.2	93.4	111.2	186.6	137.0
June	106.7	115.0	135.6	161.4	198.9	157.2
July	116.1	124.9	147.4	203.5	206.5	172.4
August	125.1	134.6	158.7	180.9	205.8	155.0
September	87.8	94.4	111.6	132.8	164.7	142.8
October	73.1	78.6	92.9	110.5	124.0	115.6
November	63.0	67.7	79.9	95.1	81.6	103.2
December	41.2	44.3	52.3	62.2	60.5	71.3
Seasonal mm	**864.9**	**930.5**	**1098**	**1327**	**1607**	**1387**
Second season 2016						
January	16.4	18.4	21.4	25.6	62.3	48.98
February	25.4	28.4	33.2	39.9	83.4	50.96
March	46.4	51.5	60.2	72.2	121.8	69.75
April	66.2	73.7	86.1	103.1	159.6	96.9
May	77.6	86.5	101.2	121.4	188.8	116.25
June	107.1	119.4	139.5	167.4	209.7	135.6
July	113.2	126.1	147.4	197.7	214.5	146.01
August	124.0	138.2	161.4	195.6	193.4	167.09
September	82.1	91.4	106.8	115.0	160.8	95.7
October	68.9	76.7	89.6	107.5	126.8	96.1
November	63.0	70.1	80.6	86.6	84.9	77.1
December	41.2	45.9	49.9	59.9	63.9	65.1
Seasonal mm	**831.4**	**926.1**	**1077**	**1292**	**1670**	**1166**

1.2.1. Crop coefficient (Kc):

Two different equations were used to assess the extent of closeness of each estimate with the actual values obtained by direct measurement with (I_1) irrigation when 30 % of available soil moisture was depleted . These equations are the Doorenbos- Pruitt equation using the water model, and Pan evaporation equation. The Pan evaporation formula was the closest compared with the Doorenbos-Pruitt equation because the ET crop calculated from this formula differed slightly from the actual ET value. The actual crop coefficient (Kc) was calculated for the different types of mulching is shown in Table (5). The maximum un-mulching values (1.18 and 1.35) were obtained in July, while the minimum values (0.76 and 0.52) were obtained in January with an average of 0.92 and 1.05 over the whole two, respectively. The actual (Kc) increased from January to July, then declined in November and December in both seasons. The actual minimum (Kc) values were obtained under plastic mulch, followed by banana leaves then rice straw mulch treatment, while unmulched came in the four rank in this respect.

Table 5: Calculated and theoretical crop coefficient Kc for banana plants under mulched and un-mulched conditions during 2015 and 2016 seasons.

	Doorenbos- Pruitt				Pan evaporation			
	First season 2015							
Months	**Black polyethylene plastic**	**Banana leaves**	**Rice straw**	**unmulched**	**Black polyethylene plastic**	**Banana leaves**	**Rice straw**	**Unmulched**
January	0.41	0.44	0.53	0.62	0.50	0.54	0.64	0.76
February	0.38	0.41	0.49	0.58	0.50	0.53	0.63	0.75
March	0.45	0.48	0.57	0.68	0.58	0.63	0.74	0.88
April	0.58	0.63	0.74	0.88	0.53	0.57	0.68	0.81
May	0.39	0.42	0.50	0.60	0.54	0.58	0.68	0.81
June	0.54	0.58	0.68	0.81	0.68	0.73	0.86	1.03
July	0.56	0.60	0.71	0.99	0.67	0.72	0.86	1.18
August	0.61	0.65	0.77	0.88	0.81	0.87	1.02	1.17
September	0.53	0.57	0.68	0.81	0.61	0.66	0.78	0.93
October	0.59	0.63	0.75	0.89	0.63	0.68	0.80	0.96
November	0.77	0.83	0.98	1.17	0.61	0.66	0.77	0.92
December	0.68	0.73	0.87	1.03	0.58	0.62	0.73	0.87
Seasonal	**0.54**	**0.58**	**0.69**	**0.83**	**0.60**	**0.65**	**0.77**	**0.92**
	Second season 2016							
January	0.26	0.30	0.34	0.41	0.33	0.38	0.44	0.52
February	0.30	0.34	0.40	0.48	0.50	0.56	0.65	0.78
March	0.38	0.42	0.49	0.59	0.67	0.74	0.86	1.04
April	0.41	0.46	0.54	0.65	0.68	0.76	0.89	1.06
May	0.41	0.46	0.54	0.64	0.67	0.74	0.87	1.04
June	0.51	0.57	0.67	0.80	0.79	0.88	1.03	1.23
July	0.53	0.59	0.69	0.92	0.78	0.86	1.01	1.35
August	0.64	0.71	0.83	1.01	0.74	0.83	1.0	1.20
September	0.51	0.57	0.66	0.72	0.86	0.96	1.12	1.20
October	0.54	0.60	0.71	0.85	0.72	0.80	0.93	1.12
November	0.74	0.83	0.95	1.02	0.82	0.91	1.05	1.12
December	0.65	0.72	0.78	0.94	0.63	0.71	0.77	0.92
Seasonal	**0.49**	**0.55**	**0.63**	**0.75**	**0.68**	**0.76**	**0.88**	**1.05**

1.3. Water use efficiency (WUE):

WUE is defined as the ratio of yield to ETa, when applied and/or stored water does not evaporate, but is used by the crop to produce additional fruits yield as a function of multiple factors, including physiological characteristics of banana, and soil characteristics, meteorological conditions and agronomic practices. Water use efficiencies WUE calculated for the different studied treatments are shown in Table (6) In general, the values of water use efficiency WUE increased with the applying of mulch treatments. The highest increase in WUE was obtained under plastic mulch followed in descending order by banana leaves, then rice straw mulch as compared to un-mulch treatments in both seasons. Average values of WUE were (6.40–6.36), (5.78–5.62), (4.20–4.08) and (3.19-2.64) kg/m^3 for plastic mulch, banana leaves, rice straw mulches and un-mulch in both seasons, respectively.

This may be due to yield increment under mulching treatments as a result of increasing water availability and decreasing both the weed and water evapotranspiration. Plastic sheet, banana leaves and rice straw mulching generally led to increase WUE by 118%, 95.2% and 41.8% over the un-mulched treatment, respectively in both seasons. Significant differences in WUE among treatments were obtained. These results are in agreement with those obtained by El-Henawy (2006) who reported that, WUE values under soil mulching were higher than under bare soil

Table 6: Water use efficiency (WUE, kg/m^3 consumed water) for banana plant as affected by soil moisture regimes and different mulching treatments.

Depletion / Available water %	Black polyethylene plastic	Leaves of banana	Rice straw	Unmulched	Mean
	First season: 2015				
30 % A.S.M. (I_1)	6.32e	5.81cd	4.06b	2.94a	**4.78A**
60 % A.S.M. (I_2)	6.48ef	5.76c	4.35b	3.44a	**5.01A**
Mean	**6.40D**	**5.78C**	**4.20B**	**3.19A**	
	Second season: 2016				
30 % A.S.M. (I_1)	6.27fg	**5.59e**	4.05cd	2.58ab	**4.62A**
60 % A.S.M. (I_2)	6.45f	**5.65e**	4.10c	2.71a	**4.73A**
Mean	**6.36D**	**5.62C**	**4.08B**	**2.64A**	

Means followed with the same letter (s) within each column or row are not significantly different according to Duncan's Multiple Range test at 5 % level.
I_1: irrigation when 30 % of available soil moisture was depleted.
I_2: Irrigation when 60 % of available soil moisture was depleted .

2. Vegetative growth:

Data presented in Table (7) showed the effects of tested treatments (mulching, water irrigation regime and their interaction) on growring parameters. The results indicated that of growth triats were significantly increased in the two mulching treatments (black polyethylene and banana leaves) but they were non significant in between as the means of pseudostem height and circumference and number of leaves of Williams banana plants were (353.8 & 352.5) and (356.2 & 355.0 cm), (94.33 & 93.67 cm) and (96.00 & 95.33 cm) and (12.17 & 12.00) and (12.33 & 12.17), in the two seasons, respectively, at shooting stage compared with the control. All increases were a mulch dependent.

Table 7: Effect of water irrigation regime, mulching treatments and their interaction on vegetative growth of Williams banana plants during 2015 and 2016 seasons.

Irrig.regime / Mulching	Psedostem length (cm)			Psedostem circum. (cm)			No. leave /plant		
	I_1^*	**I_2^{**}**	**Mean**	**I_1^***	**I_2^{**}**	**Mean**	**I_1^***	**I_2^{**}**	**Mean**
	First season: 2015								
Unmulched	319.0e	308.7f	**313.8C**	87.33d	79.67e	**83.50C**	10.00d	9.33d	**9.67C**
Rice straw	339.7c	327.3d	**333.5B**	90.67c	87.33d	**89.00B**	11.00c	10.00d	**10.50B**
Banana Leaves	355.7a	349.3b	**352.5A**	95.00ab	92.33bc	**93.67A**	12.33ab	11.67bc	**12.00A**
Black polyethylene	358.0a	349.7b	**353.8A**	95.67a	93.00a-c	**94.33A**	12.67a	11.67bc	**12.17A**
Mean	**343.1A**	**333.8B**		**92.17A**	**88.08B**		**11.50A**	**10.67B**	
	Second season: 2016								
Unmulched	321.0e	308.7f	**314.8C**	88.33e	80.67f	**84.50C**	10.67cd	9.67e	**10.17C**
Rice straw	340.3c	330.3d	**335.3B**	92.00cd	90.00de	**91.00B**	11.33bc	10.00de	**10.67B**
Banana Leaves	359.3a	350.7b	**355.0A**	98.67a	93.33c	**96.00A**	12.67a	11.67b	**12.17A**
Black polyethylene	360.0a	352.3b	**356.2A**	96.67ab	94.00bc	**95.33A**	12.67a	12.00ab	**12.33A**
Mean	**345.2A**	**335.5B**		**93.92A**	**89.50B**		**11.83B**	**10.83B**	

Means followed with the same letter (s) within each column or row are not significantly different according to Duncan's Multiple Range test at 5 % level.
I_1: irrigation when 30 % of available soil moisture was depleted.
I_2: Irrigation when 60 % of available soil moisture was depleted .

However, as the differences between the two levels of irrigation water regime were significant, the highest values of pseudostem height and circumference and No. leaves were obtained when appling I_1, 30 % of avaible soil moisture treatment comaped with (I_2, 60 %) of available moisture. The interaction treatments showed the best results in this respect. It recorded at the mulching with either both banana leaves or black polyethylene palstic the highest values of pseudostem height, circumference and number of leaves/plant. The control plants showed the lowest values in the two seasons.

Similar observations were also attained by Liu *et al*. (2014) and Liang *et al*. (2002), who reported that, the benefits of using mulch in orchards have been reported in many parts of the world to protect plants from extreme transpiration fluctuation and regulation of soil temperature. Moreover, using mulches help in moisture conservation and reduction of evaporation (Sinkeviciene *et al*. 2009), reserve water at the root zone (Khalifa, 1994), increased soil organic matter (Kiristina *et al*. 2013), and it is considered as a source of plant nutrients (Hostetler *et al*. 2007).

3. Vegetative growth measurements and cycle duration.

Data in Table (8) show that treatments of mulching, water irrigation regime and their interaction caused earliness in blooming and maturity relative to the control. Using both mulching and water irrigation regime together at the highest level of irrigtion and mulched by black polyethylene was significantly preferable than using each of them alone on decreasing time of blooming and maturity. Plants treated with irrigation water regime at 30 % and mulched with black polyethylene, bloom earlier by about 55 to 60 days compared to the control in both seasons. These results in general are in agreement with those of Barman *et al*. (2005) who recorded significant improvement in number of days taken for the first floret opening, spike length and rachis length with the application of paddy straw mulch in gladiolus. Chawla (2006) obtained maximum plant height (70.91 cm), plant spread (53.05 cm) and highest number of branches (18.54) at harvest in marigold cv. Double mix with application of black plastic mulch compared to other mulching treatment.

Table 8: Effect of water irrigation regime, mulching treatments and their interaction on time to flowering (days), time to harvest (days) and cropping cycle (life cycle duration) of Williams banana plants during 2015 and 2016 seasons.

Irrig.regime / Mulching	Time to flowering (days)			Time to harvest (days)			Cropping cycle (life cycle duration)		
	I_1*	I_2**	Mean	I_1*	I_2**	Mean	I_1*	I_2**	Mean
	First season: 2015								
Unmulched	380.7a	374.3b	**377.5A**	128.7b	137.3a	**133.0A**	505.3b	521.7a	**513.5A**
Rice straw	357.7c	385.7a	**371.7B**	121.7d	126.0bc	**123.8B**	486.0c	506.3b	**496.2B**
Banana Leaves	351.7cd	374.0b	**362.8C**	113.0e	124.3cd	**118.7C**	465.3d	472.3d	**468.8C**
Black polyethylene	347.3d	369.3b	**358.3D**	111.0e	126.7bc	**118.8D**	455.3e	451.7e	**453.5D**
Mean	**359.3B**	**375.8A**		**118.6B**	**128.6A**		**478.0B**	**488.0A**	
	Second season: 2016								
Unmulched	384.0b	414.3a	**399.2A**	132.0b	141.3a	**136.7A**	515.0b	529.7a	**522.3A**
Rice straw	359.7d	379.0b	**369.3B**	125.7c	129.7b	**127.7B**	495.0c	511.0b	**503.0B**
Banana Leaves	355.0d	372.3c	**363.7C**	115.7d	128.3bc	**122.0C**	467.7e	478.0d	**472.8C**
Black polyethylene	353.3d	370.3c	**361.8D**	114.7d	125.3c	**120.0D**	463.3e	470.7de	**467.0D**
Mean	**363.0B**	**384.0A**		**122.0B**	**131.2A**		**485.3B**	**497.3A**	

Means followed with the same letter (s) within each column or row are not significantly different according to Duncan's Multiple Range test at 5 % level.
I_1: irrigation when 30 % of available soil moisture was depleted.
I_2: Irrigation when 60 % of available soil moisture was depleted .

Bunch weight and yield:

Data averaged in Table (9) showed the bunch weight (kg/tree) or yield (ton/fed) with respect to the effect of some mulching treatments of Williams banana plant. There were significant effects between the two moisture levels (30 % and 60 %) on the bunch weight and yield in both seasons of study. Moreover, both mulching treatments (ployethylene plastic and banana leaves) gave the superior results of bunch weight and yield during the two seasons. In addition, the interaction treatments indicated that using either black polyethelen plastic or banana leaves with irrigation regime at 30 % was significantly superior than using unmulching treatment in improving weight of bunch and yield under the same conditions of study. On the other hand, the least values of the recorded parameters were statistically exhibited and always in concomitant to the untreated banana plant (control). Moreover, using mulches help in moisture conservation and reduction of evaporation (Sinkeviciene *et al*. 2009), reserve water at the root zone (Khalifa, 1994), increased soil organic matter (Kiristina *et al*.

2013), and it is considered as a source of plant nutrients (Hostetler *et al*. 2007). Many kinds of mulching are used in production practices.

Table 9: Effect of water irrigation regime, mulching treatments and their interaction on bunch weight/plant (kg) and yield (ton) of Williams banana plants during 2015 and 2016 seasons.

Irrig. regime / Mulching	Bunch weight/ plant (kg)			Yield (ton) / fed		
	I_1^*	I_2^{**}	Mean	I_1^*	I_2^{**}	Mean
First season: 2015						
Unmulched	18.18d	13.59f	15.89D	16.36e	15.10f	14.30D
Rice straw	20.79b	17.85de	19.32C	18.71b	16.06d	17.39C
Banana Leaves	25.21a	20.10c	22.66AB	22.69a	18.09bc	20.39A
Black polyethylene	25.50a	20.94b	23.22A	22.95a	18.85b	20.90A
Mean	22.35A	18.12B		20.18A	16.31B	
Second season: 2016						
Unmulched	15.54e	13.05f	14.30D	13.99e	11.75f	15.89D
Rice straw	20.37b	16.50d	18.44C	18.33b	14.85d	22.15C
Banana Leaves	24.16a	19.56c	21.36B	21.74a	17.60c	23.73B
Black polyethylene	24.33a	20.10b	22.22A	21.90a	18.09b	24.68A
Mean	20.85A	17.30B		24.00A	19.22B	

Means followed with the same letter (s) within each column or row are not significantly different according to Duncan's Multiple Range test at 5 % level.
I_1: irrigation when 30 % of available soil moisture was depleted.
I_2: Irrigation when 60 % of available soil moisture was depleted .

Fruit physical properties (Fruit weight, length and diameter):

Results in Table (10) show the effect of irrigation regime and mulching treatments on finger weight, length and finger diameter. It is clear from these results that, irrigation regime of soil moisture (I_1, 30 %) gave higher finger weight, finger length and diameter (127.0 & 138.7 g), (18.50 & 19.33 cm) and (3.55 & 3.63 cm) compared with (I_2, 60 %) in the first and second seasons, respectively. On the other hand, the highest significant values of mulching treatments acquired by black polyethylene and banana leaves were non significant between themselves (127.2 & 125.3 gm) and (125.0 &122,3), for finger weight, (19.33 & 18.50 cm) and (19.50 & 18.67 cm) for finger length and (3.58 & 3.48) and (3.62 & 3.52) for finger diameter, in the two seasons respectively than unmulched treatments of this study.

Additionally, the interaction effect between irrigation regime and mulching on fruit weight, length and diameter of Williams cv. banana plants presented in Table (10) show that the means of these parameters were significantly varied due to irrigation regime and/or mulch treatments in both seasons. However, the highest values were scored by plants mulched with either black polyethylene or banana leaves treatments + (I_1, 30 %) available of soil moisture, while the lowest values were observed unmulched in plants. The heaviest finger (140 & 138 g), longest finger (21.0 & 20.33 cm) and thickest finger (3.97 & 3.87 cm) in the first season and the heaviest finger (138.7 & 136.0 g), longest finger (23.00 & 21.67) and thickest finger (4.07 & 3.93 cm) in the second one were obtained by the interaction treatment mentioned before. Whereas, the lowest records were attained by irrigation at 60% of available soil moisture + unmulched gave the lightest finger (97.7 & 94.3 g), shortest finger (11.67 & 11.33 cm) and thinnest ones (2.60 & 2.65 cm) in both tested seasons, respectively.

These findings were documented by those obtained by Neilsen *et al*. (1986) and Thakur *et al*. (1997) on apple trees and Zeerban (2004) on grapevines as they mentioned that soil mulching treatment increased leaf mineral content than polyethylene mulching one. These results may be attributed to the mulching effect on improving root growth and its respiration rate due to modifying soil temperature and moisture content, which in turn, created a suitable condition for soil microorganisms. These modifications in soil condition may be responsible for increasing nutrients absorption via roots.

Table 10: Effect of water irrigation regime, mulching treatments and their interaction on growth cycle duration of Williams banana plants during 2015 and 2016 seasons.

Irrig.regime / Mulching	Finger weight (gm)			Finger length (cm)			Finger diameter (cm)		
	I_1^*	I_2^{**}	**Mean**	I_1^*	I_2^{**}	**Mean**	I_1^*	I_2^{**}	**Mean**
	First season: 2015								
Unmulched	102.7e	97.7f	**100.2C**	14.67d	11.67e	**13.17C**	3.00cd	2.60e	**2.80C**
Rice straw	127.3b	105.7d	**116.5B**	18.00b	15.00d	**16.50B**	3.37b	2.93d	**3.15B**
Banana Leaves	138.0a	112.7c	**125.3A**	20.33a	16.67c	**18.50A**	3.87a	3.10cd	**3.48A**
Black polyethylene	140.0a	114.3c	**127.2A**	21.00a	17.67bc	**19.33A**	3.97a	3.20bc	**3.58A**
Mean	**127.0A**	**107.6B**		**18.50A**	**15.25B**		**3.55A**	**2.96B**	
	Second season: 2016								
Unmulched	110.3c	94.3e	**102.3D**	13.67e	11.33f	**12.50C**	3.10cd	2.60e	**2.85C**
Rice straw	123.3b	106.7d	**115.0C**	19.00c	14.00e	**16.50B**	3.40b	2.93d	**3.17B**
Banana Leaves	136.0a	108.7cd	**122.3B**	21.67b	15.67d	**18.67A**	3.93a	3.10cd	**3.52A**
Black polyethylene	138.7a	111.3c	**125.0A**	23.00a	16.00d	**19.50A**	4.07a	3.17c	**3.62A**
Mean	**127.1A**	**105.3B**		**19.33A**	**14.25B**		**3.63A**	**2.95B**	

Means followed with the same letter (s) within each column or row are not significantly different according to Duncan's Multiple Range test at 5 % level.
I_1: irrigation when 30 % of available soil moisture was depleted.
I_2: Irrigation when 60 % of available soil moisture was depleted .

Economic analysis:

The economical comparative study between different treatments that shown in Table (11) were calculated at the average of the two studied years. Total cost of production, incomes profits (L.E./fed) and net return (LE/fed.) of banana plant as affected by available soil moisture depletion and mulching treatments.

Banana leaves and black polyethylene approximately with two season of mulching treatments were superior in total income (LE/fed) which in turn increased the net return (LE/fed) (118389 & 118011 LE), respectively comparing with other treatments.

Table 11: Economic analysis as affected by available soil moisture depletion treatment and mulching treatments (average yield and applied water of 2 years).

Treatments		Cost of production					Incomes Profits (L.E. /fed.)			**Net return (LE/fed)**
		Field practices	Hand hoeing	Mulching	Water cost Irr. (LE)	Total (LE/fed)	Fruit LE/Kg	Kg /fed	Total (LE/fed)	
I_1 30%	Un-mulched	12300	1700	0	2340	16340	6	15174.0	91044	74704
	Rice straw		1200	1100	1800	16400	6	18522.0	111132	94732
	Banana leaves		900	0	1710	14910	6	22216.5	133299	118389
	Black polyethylene plastic		1400	1150	1680	16530	6	22423.5	134541	118011
I_2 60%	Un-mulched	12300	1700	0	1980	15980	6	11988.0	71928	55948
	Rice straw		1200	1100	1680	16280	6	15457.5	92745	76465
	Banana leaves		900	0	1460	14660	6	17847.0	107082	92422
	Black polyethylene plastic		1400	1150	1380	16230	6	18468.0	110808	94578

Conclusion

Mulched treatments were more effective in reducing water evaporation, increasing water use efficiency and banana plants because is shallowest roots yield compared to un-mulched treatments. Plastic mulch and/or banana leaves was more effective in reducing evapotranspiration and improving water use efficiency as compared to rice straw mulch and unmulched. Applying banana plants mulch would lower these costs and increases the environment benefit compared to plastic mulch. It is suggested that increasing the applied rate of banana plants can raise its performance in reducing evaporation. The results also concluded that the (Kc) values were lower under mulching compared to un-mulching.

References

Allen, R.G., L.S.Pcreira, D. Raes and M. Smith, 1998. Crop evapotranspiration. Irrigation and Drainage Paper No. 56, FAO, Rome, Italy.

Barman, D., K.Rajni, P. Rampal and R. C.Upadhyay, 2005. Effect of mulching on cut flower production and corm multiplication in gladiolus. Journal of Ornamental Horticulture, 8:152-154.

Chawla, S. L., 2006. Effect of irrigation regimes and mulching on vegetative growth, quality and yield of flowers of African marigold. Ph.D. Thesis, Department of Horticulture, Maharana Pratap University of Agriculture and Technology, Udaipur.

Devitt, D.A., R.L. Marris and D.S. Neuman, 1994. Evapotranspiration and growth response of three woody ornamental species placed under varying irrigation regimes. J. Amer. Soc. Hort. Sci., 119 (3): 452-457.

Donk-van, S.J., E.W. Tollner, J.L. Steiner and S.R. Evett, 2004. Soil temperature under a dormant Bermudagrass mulch: Simulation and measurement. American Society of Agricultural Engineers, 47(1): 91-98.

Doorenbos, J. and A. H. Kasam, 1986. Yield response to water. Irrigation and Drainage Paper No. 33, FAO, Rome, Italy.

Doorenbos, J and W.O. Pruitt, 1984. Crop water requirements. Irrigation and Drainage paper No. 24. FAO, Rome, Italy

Doorenbos, J. and W.D. Pruitt, 1977. Guidelines for predicting crop water requirements. FAO Irrigation and Drainage Paper No. 24, (revised) FAO, Rome, Italy.

Duncan, D.B., 1955.Multiple range and multiple F. Tests, Biometrics, 11, 1-24.

El-Henawy, A.S., 2006. Effect of drip irrigation and soil mulching on some soil properties, yield and quality of "Navel" orange trees at North Delta. Ph.D. Thesis, Fac . Agric., Kafr El-Sheikh, Tanta Univ., Egypt.

FAO, 1979Yield response to water. Doorenbos J. and A. H. Kassam. Irrigation and Drainage paper No. 33 Rome, Italy 193p.

Gimenez, C., R.F. Otto and N. Castilla, 2002. Productivity of leaf and root vegetable crops under direct cover. Scientia Hort., 94: 1-11.

Hostetler, G., I.A. Merwin, M.G. Brown, and O. Padilla-Zakour, 2007. Influence of under vine floor management on weed competition, vine nutrition and yields of Pinot noir. Amer. J. Enol. Viticult., 58: 421–430.

Hu, Y. and U. Schmidhalter, 2005. Drought and salinity: A comparison of their effects on mineral nutrition of plants. J. Plant Nutr. Soil Sci., 168: 541– 549

Ibrahim, M.A., 1981. Evaluation of different methods for calculating potential evopotranspiration in north Delta region. Ph .D. thesis, Fac. Agri. Alex. Univ

Israelson, O. W. and V. E. Hansen, 1962. Irrigation Principles and Practices, 3rd ed., John Willey and Sons Inc., New York, USA.

Jain, N., H.S.Chauhan, P.K. Singh and K.N. Shukla, 2000. Response of tomato under drip irrigation and plastic mulching. In: Proceeding of 6th International Micro-irrigation Congress, Micro-irrigation Technology for Developing Agriculture. 22-27 October 2000 South Africa.

Jones, J.W., L.H. Allen, S.F. Shin, J.S. Rogers, L.S. Hammond, A. G. Smajstrala and J.D. Martsolf, 1984. Estimated and measured evapotranspiration for Florida climate, crops and soils. Rep. 840. University of Florida, Gainesville.

Khalifa, M.R., 1994.Effect of different types of mulching on water consumptive use of " Valencia" orange trees. J. Agric. Res., Tanta Univ., 20 (3): 591- 602

Khurshid, K., M. Iqbal, M.S. Arif and A. Nawaz, 2006. Effect of tillage and mulch on soil physical properties and growth of maize. Int. J. Agric. Biol., 5: 593–6.

Kiristina, B., D. Todaugine, R. Pupaliene and A. Sinkeviciene, 2013. Effect of organic mulches on the content of organic carbon in the soil. Estonian J. Ecology, 62 (2): 100-106.

Klute, A., 1986. Methods of Soil Analysis: Part I: Physical and Mineralogical Methods. (2nd Ed), Am. Soc. Agron., Monograph No. 9, Madison, Wisconsin. USA.

Levitt, D.G., J.R. Simpson and J. L. Tipton, 1995. Water use of two landscapes tree species in Tucson. J. Amer. Soc. Hort. Sci., 120: 409-416.

Liang, Y.L., C.E. Zhang, and D.W. Guo, (2002). Mulch types and their benefit in cropland ecosystems on the loess plateau in China. J. Plant Nutrition, 25 (5): 945-955.

Liu, Yi, Wang, Jing, Liu, Dongbi, Li, Zhiquo, Zhang, Guoshi, Zhang, Tao, Yong, Xie, Juan, Pan, Junfeng and Chen, Fang (2014). Straw mulching reduces the harmful effects of extreme hydrological and temperature conditions in Citrus Orchards. Plos one. 9 (1), e87094:1-9.

Makkink, G.F., 1957. Testing the penman formula by means of lysimeters J. Inst Water Eng (11): 277-278.

Mikhael, G. B., 2007. Effect of some drip irrigation and mulching treatments on 1- Vegetative growth and nutritional status of "Anna" apple trees growing on new reclaimed soils. Minufiya J. Agric. Res., 32 (4): 1155-1174.

Mustafa, O.S., M.Arshad, I. Sattar and S. Ali, 2003. Adoption of kostiak of model to determine the soil infiltration for surface irrigation methods under local conditions. Int. J. Agric. Biol., 1: 40–2 .

Neilsen, G.h., E.J. Hogue and B.G. Drought, 1986. Orchard soil management on soil temperature and apple trees. Canadian J. Soil Sci., 66: 701-711 .

Saif, U., M. Matsudo, M. Faros, S. Hussain and A. Habib, 2003. Effect of planting patterns and different irrigation levels on yield and yield component of maize (*Zea mays* L.). Int. J. Agric. Biol., 1: 64–69.

Shaw, R.H., 1959. Water use from plastic covered and uncovered corn plots. Agron. J., 51: 172-173

Snedecor, G.W. and W.G. Cochran, 1980. Statistical Methods. 6th Ed. The Iowa St. Univ., Press. Amer., Iowa. U.S. A., pp: 363-372.

Sharma A.R., R. Singh, S.K. Dhyani, R.K. Dube, 2010. Moisture conservation and nitrogen recycling through legume mulching in rainfed maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system. Nutrient Cycling in Agroecosystems, 87: 187–197.

Sinkeviciene, A., D. Jodaugiene, R. Pupaliene and M. Urboniene, 2009. The influence of organic mulches on soil properties and crop yield. Agron. Res., 7 (1): 485-491.

Souza, E.R., A.A.A. Montenegro, S.M.G. Montene-Gro and J.A. Matos, 2011. Temporal stability and soil moisture in irrigated carrot crops in Northeast Brazil. Ag- ricultural Water Management, 99(1), 26–32.

Stackman, W.P., 1966. Determination of pore Size by the air bubbling pressure method. Proceeding UnesceSymp on water in the unsaturated zone, 366- 372.

Surendar K. K., D. D. Devi, I. Ravi, P. Jeyakumar and K. Velayudham, 2013. Studies on the impact of water deficit on morphological, physiological and yield of banana (*Musa spp*.) cultivars and hybrids. International J. of Agric. Sci., 3 (4):473- 482.

Thakur, G.C., T.R. Chadha, H.S. Verma and J. Kumar, 1997. Effect of ciean cultivation, mulching and sod culture on mineral nutrition and root growth of apple cv. Red Delicious. Indian J. Hort., 54 (10):53-57.

Vavrina C.S. and F.M. Roka, 2000. Comparison of plastic mulch and bare ground production and economics for short-day onion in a semitropical environment. Horticultural Technol., 10: 326-330.

Verma, M. L., S. P. Bhardwaj, B. C. Thakur and A. R. Bhandria, 2005. Nutritional and mulching studies in apple. Indian J. Hort., 62 (4): 332-335.

Vites, F.G. Jr., 1965. Increasing water use efficiency by Soil Management. Am. Soc. Agron., Madison, Wisc. pp. 259-274.

Weagand, G. L., 1962. Drying pattern of a sandy clay loam in relation to optimal depth of seeding. Agron., J. 54: 473-476.

Zaman, W.U., M. Arshad and A. Saleem, 2001. Distribution of nitrate-nitrogen in the soil profile under different irrigation methods. Int. J. Agric. Biol., 2: 208–9

Zeerban, S.M., 2004. Vegetative growth, yield and fruit quality of Thompson seedless grapevines as affected by some soil mulching materials. J. Agric. Sci., Mansoura Univ., 29(6):3515-3529.