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Effect of irrigation and mulching practices on maize crop and some water relations

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Abstract

The experiments were conducted at the experimental farm of Giza Agricultural Research Station, Egypt, during the summer seasons of 2014 and 2015 to study the effect of different irrigation regimes (I_1=Irrigation at 25-30%, I_2 = 50-55% and I_3 75-80% of available soil moisture depletion (ASMD) and mulching treatments white plastic film mulch (PFM), Rice straw mulch (RSM), and No mulching (NM) on (Zea mays L.). A split plot design with three replicates was used. The most important results can be summarized as follows:

The highest value of the irrigation water applied (IWA), was found to be (3451 and 3444 m^3/fed.), due to (I_1) treatment in both growing seasons, respectively. Water consumptive use (WCU) was increased in the case of frequent irrigation as in 25-30% (ASMD) than the two irrigation treatments. Also, average water use efficiency (WUE) was increased by using 25-30% of (I_1), with plastic mulch and recorded (1.64 kg/m^3), followed by 50-55 with plastic mulch (1.59 kg/m^3), and 75-80% (ASMD) treatments with plastic mulch (1.42 kg/m^3) in both seasons. The maximum value of water utilization efficiency (WUtE), was 1.06 and 1.12 kg /m^{-3} in 2014 and 2015 seasons, respectively, and was obtained from (I_2) 50-55% with plastic mulch treatments compared with no mulching treatments in the both seasons. The highest significant values of ear diameter (cm), ear length ,100-grain weight (g) and grain yield of maize were obtained when irrigation was done at 25-30% (ASMD) compared with other treatments 50-55% and 75-80% (ASMD) in both seasons. The mulching with plastic gave the highest significant values of ear length and diameter (cm) as well as 100-grain weight (g) and grain yield of maize compared without mulching in both seasons. Also, results revealed that the highest significant values of ear length and diameter (cm) as well as 100-grain weight (g) and grain yield of maize were obtained by I_1 25 -30 % with plastic mulching treatment in both seasons. The highest net return (L.E.fed^{-1} 3726/fed.), and (L.E.fed^{-1} 3100/fed.), were found for 25-30% (ASMD) application with plastic or straw mulch. The study thus reveals that (ASMD) 25-30% with mulch has an explicit role in increasing the yield and net return of maize

Key words: - irrigation, mulching, maize and water relations

Introduction

Maize is considered as one of the most important cereal crops in Egypt after wheat and rice, and is grown throughout a wide range of climates, and its wide use in human and livestock feeding and industrial aspects **(Aiad *et al.* 2014).**Total annual area cultivated with maize varieties was estimated 1.7 million feddans. Total national production of maize is about 5.50 million tons, (**Economic Affairs Sector 2015).** Maize cultivation requires large quantities of water seasonally to obtain a large crop. **Ayotamuno *et al.* (2007)** reported that the maximum plant height and the other maize yield components increased with increasing irrigation water. **Abdel-Hafez *et al.* (2008)** reported that the highest value of grain yield was obtained with irrigation at 1.3 ETc (evapotranspiration) as compared to 1.0 and 0.7 ETc.

Limited water resources are the major constraints on crop production **(Liu *et al.* 2009)**. In attempting to offset the water limitations and high temperatures, soil mulching (with plastic or straw) reduces evaporation, modifies soil temperature and thereby affects crop yields, as one of the most important traditional techniques **(Wei *et al*. 2015)**. Many investigations have been conducted to check the water loss during soil surface evaporation and plant transpiration. Evapotranspiration, consisting of water movement from soil surface and plant transpiration, is a main component of water balance. Grain yields may be described as a linear function of evapotranspiration for most crops **(Zhang *et al.* 2007). Mansouri *et al*. (2010)** reported that irrigation water can be conserved and yields maintained in maize plant (as sensitive crop to drought stress) under water limited conditions through improved fertilizer managements. **Hafiz** and **Ewis (2015)** reported that the highest values of the amount of applied water (AW) and water consumptive use (WCU) were recorded when plants were subjected to irrigation at 25-30% soil moisture depletion. **Younis *et al.* (2010)** showed that supplying plants with a water level of 40% from available soil water and 30 kg K_2O/fed were effective on raising the productivity of fruit yield and essential oil of fennel plant.

Mulching is a desirable management tool for soil water conservation as it increases soil temperature and soil quality as well as improved crop yield and water use efficiency**.** Plastic mulching has commonly been used for adaptation to water scarcity and for improving soil water management, increasing soil moisture, promoting crop growth and increasing maize yield by 26.1% during the experimental period compared to the control treatment. Moreover, water use efficiency also significantly increased by 25.1% **(Vial et al. 2015; Rong *et al.* 2016 and Rui *et al.* 2016).** Plastic mulch and different irrigation levels significantly increased the water use efficiency from 22.43 % to 10.97 % and getting good maize yield **(Sajid *et al.* 2015).** The plastic film mulching can significantly increase crop yields and water use efficiency (WUE), primarily by providing favorable soil moisture and temperature for crop growth **(Jie *et al.* 2015). El-Nady and Borham (2009),** reported that the increase in (WUE) was about 24.0 % and 14.0 % under plastic and rice straw mulches as compared to un-mulched treatment, respectively. Plastic mulch was more effective than rice straw in decreasing water evapotranspiration, increasing water use efficiency and grain yield of maize.

The main objectives of this study are to investigate the effect of different available soil moisture depletion (ASMD) treatments and mulching treatments with white plastic film mulch (PFM), Rice straw mulch (RSM), and No mulching (NM) on maize yield and its components as well as some water-crop relations. This research could be helpful for water management strategies for maize production in Egypt.

Materials and Methods

A field experiment was carried out at the experimental farm of Giza Agricultural Research Station, Egypt. The farm is located at 31.21 longitude, 30.01 latitude and 30 m altitude above the mean sea level, during summer seasons (2014 and 2015). Some meteorological data for Giza Agricultural Research Station during the two growing seasons are presented in Table 1.

Table 1. Mean values of meteorological data of the 2014 and 2015 summer seasons and the calculated reference evapotranspiration values.

Month	Season	Temperature °C			Relative Humidity (%)	Wind Speed ($m\ sec^{-1}$)	ETo ($mm\ day^{-1}$)
		Max.	Min.	Mean			
May	2014	41.49	25.17	33.33	29.07	4.59	11.3
	2015	37.91	22.15	30.03	25.35	4.05	10.8
June	2014	37.70	22.42	30.06	35.31	4.84	9.8
	2015	35.35	20.34	27.84	32.53	4.31	9.6
July	2014	34.68	20.76	27.72	41.33	5.09	7.7
	2015	29.78	15.01	22.39	34.56	3.70	7.2
August	2014	27.73	16.08	21.90	44.82	3.67	5.3
	2015	26.99	14.04	20.51	44.27	3.31	5.2
September	2014	37.7	23.4	30.55	47.00	1.9	4.79
	2015	35.4	22.3	28.85	44.3	1.9	4.67

The experiment design was a split plot with three replicates. The tested variables were as follows:

Main plots (irrigation):
1- Irrigation at 25-30% of available soil moisture depletion (ASMD)
2- Irrigation at 50-55% of (ASMD)
3- Irrigation at 75-80% of (ASMD)

Sub-plots (Mulching):
1- White plastic film mulch (PFM)
2- Rice straw mulch (RSM), and
3- No mulching (NM)

The experimental units were separated from each other by a belt (2.0 m width) to avoid lateral movement of irrigation water. Rice straw mulch (RSM) was applied by hand at a rate of 2.1 ton/fed. 20 days after sowing. A 0.3 cm thick plastic sheet was used to cover the soil area and planting seeds in the plastic slots.

Maize seeds (Single-Cross 10 hybrid) were sown at a rate as 15 kg fed-1 on 26th and 30th of May in 2014 and 2015 summer seasons, respectively. Fertilization was managed according to the recommendation of the Ministry of Agriculture in Egypt. The field was fertilized with 30kg P_2O_5/fed in the form of super phosphate (15% P_2O_5), and 48 kg K_2O/fed added in the form of potassium sulfate (48% K_2O), both fertilizers were applied during soil preparation. Nitrogen fertilizer (120 kg N/fed) was applied in the form of ammonium nitrate (33.5% N) and applied in two equal doses before 2nd and 3rd irrigations. Harvest was done on 20th 25th of September in 2014 and 2015 seasons respectively. Surface irrigation system was used to convey the water to the experimental plots, and the amounts of the irrigation water applied was estimated by using flume through the whole growing season and calculated as m^3/fed. according to **Early, (1975).**

Soil moisture content was gravimetrically determined in soil samples taken from consecutive depths of 15 cm. down to a depth of 60 cm. Soil samples were also collected just before each irrigation, 48 hours after irrigation and at harvest time. Irrigation water was applied when the moisture content reached the desired available soil moisture in each treatment. Field capacity was determined in the field **(Garcia, 1978).**Permanent wilting point and bulk density were executed according to **Black *et al.* (1985**) to a depth of 60 cm. Available soil moisture content was calculated by subtracting wilting point from field capacity is presented in Table 2 as well as some physical and chemical properties of the experimental soil were determined according to **Klute (1986**) and **Page *et al.* (1982)** and listed in Table 3.

Table 2. Soil water constants and bulk density values of the experimental soil

Depth (cm)	Field capacity (%, w/w)	Wilting point (%, w/w)	Available water (%, w/w)	Bulk density (gcm^{-3})
0.0 – 15	40.9	18	22.9	1.15
15 – 30	37.8	17	20.8	1.24
30 - 45	31.4	17.1	14.3	1.20
45 – 60	27.7	16.5	11.2	1.28
Mean	34.45	17.15	17.3	1.28

Table 3. Some physical and chemical properties of the experimental soil

seasons	Particle size distribution			Textural class	Chemical properties					
	Clay	Silt	Sand		O.M. (%)	EC dS/m	pH	Available (ppm)		
	%							N	P	K
2014	34.9	36.8	28.3	Clay loam	1.05	0.65	7.9	31.6	16.3	315.8
2015	35.1	36.1	28.8		0.95	0.69	7.8	30.0	15.8	305.7

The following characters were measured:
1- Ear length (cm) 2- Ear diameter (cm) 3- 100-grain weight (g) 4- Grain yield ton/fed.

The data collected for the above variables were subjected to statistical analysis using analysis of variance (ANOVA) technique **(Snedecor and Cochran, 1980).** The means were compared using Least Significant Difference (LSD) at 5% probability level according to **Waller and Duncan (1969).**

Soil- water relationships:

Amount of the irrigation water applied:

Applied irrigation water was recorded by flume installed in the main unit of irrigation water according to the following equation **(Michael, 1978).**

$$Q = CA \sqrt{2gh} \quad x\ 10\text{-}3$$

Where:

Q = discharge through orifice, (L/sec.).
C = coefficient of discharge, (0.61).
A = cross-sectional area of the orifice, (cm2).
g = acceleration of gravity, (981 cm/sec2).
h = pressure head, causing discharge through the orifice (cm).

Seasonal consumptive use (ETC):

On determining the crop water consumptive use (ETC), soil samples were collected before and 48 hours after each irrigation, as well as at harvest time in 15 cm increment to 60 cm depth of the soil profile. The crop water consumptive use between two successive irrigations was calculated according to the equation given by **Israelsen and Hansen (1962)** expressed as:

$$Cu = \frac{D.Bd.[Q2 - Q1]}{100}$$

Where:
Cu = consumptive use or actual evapotranspiration (cm).
D = Effective root zone depth (cm).
Bd = soil bulk density (gcm-3).
Q2 = soil moisture content (%, w/w) after irrigation.
Q1 = soil moisture content (%, w/w) before the next irrigation.
Water consumptive use as (m^3 fed^{-1}) was obtained by multiplying the value of WCU (m) by 4200 m^2

Water use efficiency (WUE)

WUE it is defined as the ratio of yield to ET, when applied and/ or stored water does not evaporate but is used by the crop to produce additional grain yield. a function of multiple factors, including physiological characteristics of maize, and soil characteristics, meteorological conditions, and agronomic practices. Water use efficiency in kg m-3 was estimated for each treatment according to the equation described by **Vites (1965)** as follow:
WUE (kg m^{-3}) = Grain yield (kg fed^{-1}) / Consumptive use (m^3 fed^{-1})

Water utilization efficiency (WUtE):

Water utilization efficiency (WUtE) values were calculated according to **Jensen (1983)** as follow: WUtE (kg m^{-3}) = Grain yield (kg fed^{-1})/Applied irrigation water (m^3 fed^{-1}) Applied irrigation water was recorded by a flow meter installed in the main unit of irrigation water.

Economic analysis

Economic analysis aims to study the economic evaluation of the experimental treatments. This study will be done through calculation of the differences between costs of production (L.E. fed^{-1}) and incomes profits (L.E.fed^{-1}) to obtain the net return (L.E.fed^{-1}) of treatments; will be shown the best treatments that achieved the highest net return (L.E.fed^{-1}). All costs of production and incomes profits were mathematically changed to be per fed. On the other hand, incomes profits were calculated from the actually prices of average maize production per ard. / fed^{-1} equal 400 L.E.

Results and Discussion

Water Relations:

Irrigation water applied (IWA, m^3/fed. and cm/fed.)

The amounts of irrigation water applied (m^3 fed^{-1}) were measured and estimated for all treatments. Data presented in Table 4 clearly show that the values of water applied were increased under 25-30% of (I_1) compared with the other two irrigation treatments of 50-55% $I_2$and 75-80% I_3 of available soil moisture depletion (ASMD). The highest values were (3451 and 3444 m^3/fed.) due to (I_1) treatment, where, the lowest values were obtained under (I_3) treatment as (3193 and 3187 m^3/fed.) in the two growing seasons, respectively. Also, data reveal that 75-80% irrigation treatments (I_3) could save about 8% of the applied water, compared with 25-30% (I_1) in both growing seasons, respectively. In addition, under 50-55% irrigation treatment (I_2) the same trend was noticed with reduction percentages values reached to 6.28 and 2.31%, as compared with (I_1).This is logic and expected results, this might be due to increasing number of irrigations accompanied with reducing irrigation period and hence increasing amount of the irrigation water applied. These results are in harmony with those obtained by **Younis *et al.* (2010) and Hafiz and Ewis (2015).**

Table 4. Amounts of irrigation water applied (m^3/ fed^{-1}) under the adopted irrigation and mulching treatments of maize in the two growing seasons**.**

Treatments		Seasonal water applied 2014	Seasonal water applied 2015	Average of the two seasons
		M^3 fed^{-1}		M^3 fed^{-1}
I_1 25-30%	PFM	3341	3335	3338
	RSM	3420	3400	3410
	NM	3592	3597	3595
Average Irrigation		3451	3444	
I_2 50-55%	PFM	2966	3300	3133
	RSM	3325	3345	3335
	NM	3450	3454	3452
Average Irrigation		3247	3366	
I_3 75-80%	PFM	2897	2875	2886
	RSM	3301	3295	3298
	NM	3381	3390	3386
Average Irrigation		3193	3187	
Average mulching	PFM	3068	3170	3119
	RSM	3349	3348	3348
	NM	3474	3480	3477

(PFM) = White plastic film mulch, (RSM) = Rice straw mulch and (NM) =No mulching

Regarding to mulching treatments, the values of the water applied were increased under rice straw mulching (RSM), and no mulching (NM) compared with white plastic film mulching (PFM). Data in Table 4 reveal that the adopted white plastic film mulching (PFM), gave the average lower values than of the seasonal applied water those with at (RSM), and No mulching (NM), which amounted to be 3119, 3348 and 3477 m^3 fed^{-1}, respectively. These results may be due to plastic mulches are completely impermeable to water; it therefore prevents direct evaporation of moisture from the soil and thus limits the water losses. In this case, plastic film mulch increased the amount of soil-available water and it plays a positive role in water conservation. The obtained results are in parallel with those reported by (**Vial *et al.* 2015; Rong *et al.* 2016 and Rui *et al*. 2016).**

Water consumptive use (WCU) (m^3 fed^{-1}):

Water consumptive use is defined as the water lost from the plant organs, specially leaves surface and namely transpiration besides that evaporated from the soil surface during the entire growing season. Average WCU values as affected by irrigation treatments on maize crop in both growing seasons are presented in Table 5. Data indicate that the amount of water consumptive use increased in case of frequent irrigation as in 25-30% available soil moisture depletion (ASMD) than the two irrigation treatments. This trend show that the increment in water consumptive use depends on the availability of soil moisture in root zone. These results are in agreement with those obtained by of **Hafiz and Ewis (2015).**

Table 5. (IWA, m^3/fed), seasonal consumptive use (WCU, m^3/fed), water use efficiency (WUE, kg/m^3 consumed) and Water utilization efficiency (WUtE, kg/m^3 applied) as affected by irrigation and mulching treatments of maize grain (kg/fed.) in the two growing seasons**.**

Treatments		2014					2015				
		IWA	**WCU**	**Grain**	**WUE**	**WUtE**	**IWA**	**WCU**	**Grain**	**WUE**	**WUtE**
I_1 25-30%	PFM	3341	2172	3547	1.63	1.06	3335	2168	3580	1.65	1.07
	RSM	3420	2223	2880	1.30	0.84	3400	2210	2980	1.35	0.88
	NM	3592	2335	2620	1.12	0.73	3597	2338	2820	1.21	0.78
Mean		3451	2243	3016	1.35	0.88	3444	2239	3127	1.40	0.91
I_2 50-55%	PFM	2966	1928	3130	1.62	1.06	3300	2145	3330	1.55	1.12
	RSM	3325	2161	2710	1.25	0.82	3345	2174	2790	1.28	0.83
	NM	3450	2243	2500	1.11	0.72	3454	2245	2520	1.12	0.73
Mean		3247	2111	2780	1.33	0.86	3261	2120	2880	1.37	0.89
I_3 75-80%	PFM	2897	1883	2630	1.40	0.91	2875	1869	2680	1.43	0.93
	RSM	3301	2146	2400	1.12	0.73	3295	2142	2630	1.23	0.80
	NM	3381	2198	2410	1.10	0.71	3390	2204	2520	1.14	0.74
Mean		3193	2075	2480	1.20	0.78	3187	2072	2710	1.27	0.82

Regarding to mulching treatments, the average values of WCU were increased under rice straw mulch (RSM), and no mulching (NM) compared with white plastic film mulch (PFM). Data in Table 5 reveal that the adopted white plastic film mulch (PFM), recorded the lower figures of seasonal water consumptive use than those with (RSM), and No mulching (NM), which amounted to be 2027, 2176 and 2260 m^3 fed^{-1}. in 2014 and 2015, respectively. These results may be due to that plastic mulches reduce the direct evaporation from the soil surface.

yield under mulching treatments with plastic /or rice straw which decreases weed germination growth and decrease evapotranspiration and soil water depletion. Similar studies have been carried out to check the effect of mulch on WUE and came to the same conclusion **(Mansouri *et al*. 2010; Jie et al. 2015; Sajid H. *et al.* 2015; Vial *et al*. 2015 and Rong *et al*. 2016)**. In connection, mulching increased WUE and grain yield due to the decrees in evaporation, enhanced transpiration and lead to increasing yields and WUE **(Zhang *et al.* 2007).**

Water use efficiency (WUE)

The change in the WUE of summer maize during the growing season in 2014 and 2015 is shown in Table 5. Table clearly indicates that the different irrigation practices with plastic mulching had significant effect on water use efficiency of maize. The highest average water use efficiency occurred in 25-30% (I_1), with plastic mulching, followed by 50-55, and 75-80% (ASMD) with rice straw mulching treatments in both growing seasons, respectively. Whereas 25-30%, 50-55% and 75-80% (ASMD) treatments without mulch showed the lower water use efficiency. The average values were (1.63 and 1.65 kg/m^3) due to (I_1) treatment. Whereas, the lowest average values were (1.11 and 1.15 kg/m^3) obtained due to (I_3) treatment in the two growing seasons, respectively. This may be due to the increase of maize

Water utilization efficiency (WUtE, kg m^{-3}):

Efficiency of water utilization is an important limiting factor to crop production. Water utilization efficiency (WUtE) values of maize yield affected by the tested variables during 2014 and 2015 growing seasons are presented in Table 5. Results show that the average values of water utilization efficiency (WUtE) were affected by irrigation and mulching treatments. The obtained results indicate that the average water utilization efficiency (WUtE) as affected by irrigation treatments in the first season, was 0.88, 0.86 and 0.78 kg m^{-3} under (I_1), (I_2), and (I_3) irrigation treatments, respectively. The corresponding value for the second season was 0.91, 0.89 and 0.82 kg grain m^{-3}. The increase in water WUtE in the second season compared with the first season could be attributed to the increase in grain yield resulted from irrigation treatments.

Concerning to mulching treatments, the values of average WUtE values were increased under white plastic film mulch (PFM), compared with other treatments in 2014 and 2015, respectively. Such increases are due to the higher grain yield resulted from mulching treatments.

The data for the interaction show that the highest values of WUtE were 1.06 and 1.12 kg grain m^{-3} water applied in 2014 and 2015 seasons, respectively. It was obtained from (I_1 and I_2) with plastic mulching treatment. Whereas, the lower values of WUtE 0.71 and 0.74 kg m^{-3} water applied, was obtained by (I_3) with no mulching (NM) in 2014 and 2015 seasons, respectively. These results are in agreement with those obtained by **(Ewis *et al.* 2016)**

Maize grain yield and some yield components

There were significant variations between the irrigation treatments in terms of the growth and development of maize during the 2 seasons of the experiment Table 6. Results show that the highest significant values of ear diameter (cm), 100-grain weight (g) and grain yield of maize (ton/fed.) were obtained by applying 25-30% of (ASMD) Compared with other treatments i.e. 50-55% and 75-80% (ASMD) in both seasons. The same trend was obtained by adding 50-55% of (ASMD) for100-grain weight (g) and grain yield in the first season and ear diameter in the second one, whereas ear length (cm) wasn't significantly affected in both seasons. Maize grain yield and yield components resulted from irrigating at 75-80% ASMD could be attributed to the low available soil moisture, in the root zone, under such treatment which leads to a decrease in cell division, cell elongation, photosynthesis activities and dry matter accumulation in plant as well as nutrients uptake and reproductive organs. **Abd El-Latif *et al.* (2012)** concluded that maize grain yield, ear length, ear diameter, ear weight/plant, grains weight /plant and 100 – kernel weight were significantly affected due to the adopted available soil moisture depletion levels. The highest values of such parameters were obtained from irrigation at 45% of available soil moisture depletion ASMD compared with irrigation at 75% ASMD in both seasons.

Table 6. Effect of available soil moisture depletion and mulching on grain maize yield and some its components in both seasons

Treatments	2014				2015			
	Grain yield (ton/fed)	**100-grain weight (g)**	**Ear length (cm)**	**Ear diameter (cm)**	**Grain yield ton/fed**	**100-grain weight (g)**	**Ear length (cm)**	**Ear diameter (cm)**
Irrigation								
25-30 % ASMD	3.02	32.38	20.84	3.91	3.12	32.12	20.89	3.97
50-55 % ASMD	2.78	30.49	20.71	3.82	2.88	30.12	20.04	3.87
75-80 % ASMD	2.48	30.08	20.77	3.73	2.61	29.98	20.91	3.66
L.S.D	0.268	0.757	0.211	0.058	0.124	0.815	2.039	0.109
Mulching								
PFM	3.02	33.91	21.59	4.01	3.20	33.67	21.71	4.04
RSM	2.74	31.53	20.68	3.80	2.80	31.40	20.80	3.84
NM	2.51	27.52	20.05	3.64	2.62	27.16	19.33	3.63
L.S.D	0.480	1.824	0.165	0.243	0.194	1.366	1.565	0.247
Interaction								
25-30 % ASMD + PFM	3.55	36.66	21.77	4.16	3.58	36.37	21.83	4.28
25-30 % ASMD + RSM	2.88	32.12	20.73	3.85	2.98	32.03	20.80	3.94
25-30 % ASMD + NM	2.62	28.37	20.02	3.70	2.82	27.97	20.03	3.69
50-55 % ASMD + PFM	3.13	32.66	21.60	4.00	3.33	32.37	21.80	4.09
50-55 % ASMD + RSM	2.71	31.47	20.73	3.81	2.79	31.23	20.87	3.82
50-55 % ASMD + NM	2.50	27.33	19.80	3.64	2.52	26.77	17.47	3.71
75-80 % ASMD + PFM	2.63	32.39	21.04	3.88	2.68	32.27	21.50	3.74
75-80 % ASMD + RSM	2.40	31.00	20.57	3.73	2.63	30.93	20.73	3.75
75-80 % ASMD + NM	2.41	26.86	20.33	3.58	2.52	26.73	20.50	3.50
L.S.D at 0.05	0.832	3.159	0.286	0.421	0.337	2.365	2.711	0.428

Regarding to the effect of mulching treatments on maize grain yield and some yield components, results in Table 6. Illustrate that mulching with plastic gave the highest values of all parameters under study compared with no mulching in both seasons. This improves can in turn maximize the absorption of solar radiation and enhance the yield. In this case, plastic mulching increased the amount of soil-available water by restricting evaporation and elevating deep water by capillarity and vapor transfer to the layer usable for roots under arid and semi-arid conditions. Also, straw mulching placed on the soil surface induce a variety of dynamic changes in the microclimate of the soil and the atmosphere near the soil surface. **Xu *et al*. (2015)**

study the effect of Plastic film mulching on maize growth, grain yield, and WUE compared with crops grown without mulching, and found that plastic film mulching significantly increased the maize grain yield by 15-26%. Yield increase mainly due to a great increase in dry matter accumulation pre-silking compared without mulching, which resulted from a greater dry matter accumulation rate due to the higher topsoil temperature and water content. Moreover, **Li *et al.* (2006a),** indicated that later in the growing season, straw mulching improved the above-ground microclimate, an effect that was beneficial for increasing the yield and WUE. Another positive effect of straw mulching decreased the soil evaporation.

For the interaction effect between available soil moisture depletion (ASMD) and mulching treatments on abovementioned parameters, results reveal that the highest values of such parameters were obtained by (I_1) 25 -30 % with plastic mulch treatment in both seasons. Whereas, the lowest ones were obtained by (I_3) 75 -80 % without mulching treatment in both ones. The data for the interaction show that the maximum value of maize grain yield was 3.55 and 3.58 ton/fed^{-1} in 2014 and 2015 seasons, respectively, it was obtained from I_1 with plastic mulch treatment. While, the lowest one was 2.41 and 2.52 ton/fed^{-1}, was obtained by (I_3) without mulching in 2014 and 2015 seasons, respectively. Sufficient water must be presented in an active crop root zone for germination, evapotranspiration, nutrient root absorption, root growth and soil microbiological and chemical processes that aid in the decomposition of organic matter and mineralization of nutrients. Same results obtained by **Farooq *et al.* (2009)** which found that the drought stress reduces leaf size, stem extension and root proliferation and disturb plant water relations. Moreover, **El-Sayed *et al.* (2010)** stated that decreasing irrigation water quantity gave a negative effect on plant growth. **Xu *et al.* (2015),** the maize yield following plastic mulch treatment was significant higher (19% more) than that following without mulching treatment. This yield increased as a result of plastic mulch is consistent with the results of other studies in arid and semi-arid areas.

Economic analysis

Total cost, gross return and net return of maize as affected by available soil moisture depletion (ASMD) and mulching treatments are presented in Table 7. The highest net return (L.E.fed^{-1} 3726/fed.), and (L.E.fed^{-1} 3100/fed.), were found for 25-30% available soil moisture depletion (ASMD) application with white plastic film mulch (PFM) and rice straw mulch (RSM) in average two seasons is the best choice for higher net return under the study compared with the non mulching (NM), while 75-80% with non mulching, gave higher net return (L.E.fed^{-1} 2220/fed.), compared with other plastic and straw mulching in this treatment. This is expected result and might be due to low cost of production and hence increasing net return.

Table 7. 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	Total	Grain	Ard./fed	Total	
I_1 25-30%	PFM	3000	0	2250	1205	6455	3564	25.45	10181	3726
	RSM		200	840	1231	5271	2930	20.93	8371	3100
	NM		600	0	1298	4898	2720	19.43	7771	2873
I_2 50-55%	PFM		0	2250	1131	6381	3230	23.07	9229	2848
	RSM		200	840	1204	5244	2750	19.64	7857	2613
	NM		600	0	1247	4847	2510	17.93	7171	2324
I_3 75-80%	PFM		0	2250	1042	6292	2655	18.96	7586	1294
	RSM		200	840	1191	5231	2515	17.96	7186	1955
	NM		600	0	1223	4823	2465	17.61	7043	2220

Conclusion

Plastic mulching treatment significantly affected the maize yield as it increased water use efficiency and other water relations. It may be concluded that under limited irrigation condition, plastic or rice straw mulching will be beneficial for maize as it is able to maintain better soil and plant water status, leading to higher grain yield, enhanced some water relations and highest net return of maize under soil moisture 25-30% with mulching.

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تأثير ممارسات الرى والتغطية على محصول الذرة وبعض العلاقات المائية

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أقيمت هذه التجربة فى محطة البحوث الزراعية بالجيزة – مركز البحوث الزراعية , مصر خلال موسمين زراعيين متتاليين 2014و2015، بهدف دراسة تأثير معاملات الرى و معاملات التغطية على محصول الذرة الشامية ومكوناته وبعض العلاقات المائية وكانت معاملات الري كالاتى: المعاملة الأولى: الري عند 25–30%، المعاملة الثانية: الري 50–55% والمعاملة الثالثة: الري بمعدل 75–80% من استنفاذ الماء الميسر مع معاملات التغطية بالبلاستيك، قش الأرز، وبدون تغطية. واستخدم في ذلك تصميم القطع المنشقة مره واحدة في ثلاث مكررات. وكانت أهم النتائج المتحصل عليها كما يلي:

بلغ إجمالي كمية مياه الرى المضافة أعلى قيم (3451 و 3444 م 3 / فدان) فى معاملة الرى الأولى (I_1)، فى كلا الموسمين، على التوالي. بينما زادت قيم الاستهلاك المائي مع زيادة معاملات الري من 25–30% من الماء الميسر بالمقارنة بمعاملاتي الرى الأخرى .أيضازادت قيم كفاءة استخدام المياه مع معاملة الري الأولى والتغطية بالبلاستيك بمتوسط1,64 كجم م 3 /فدان يليها المعاملة الثانية 50–55% من الماء الميسر 1,59كجم م 3 /فدان و معاملة الري الثالثة مع التغطية بالبلاستيك 1,42كجم م 3 /فدان فى كلا الموسمين. كانت اعلي كفاءة استعمالية لمياه الرى 1,06 ، 1,12 كجم / م3من معاملة الريالأولى مع التغطية بالبلاستيك بينما سجلت اقل القيم 0,71، 0,74 كجم / م3 فى موسم 2014 و 2015 من معاملة الرى الثانية 50–55% من الماء الميسر مع التغطية بالبلاستيك. أعطت معاملة الرى الأولى 25–30% اعلي القيم معنويا لقطر الساق، وزن الـ 100 حبة و محصول الحبوب مقارنة بمعاملات الري الثانية 50–55% و 75–80% من كمية الماء الميسر فى كلا الموسمين. بينما أعطت التغطية بالبلاستيك اعلي قيم معنوية مع قطر الساق / سم ، وزن الـ 100 حبة و محصول الحبوب / كجم فى كلا الموسمين. نفس النتائج لوحظت مع معاملة التغطية بقش الأرز مع قطر الساق / سم و محصول الحبوب / كجم فى الموسم الأول وطول الساق وقطر الساق فى الموسم الثاني. كما أظهرت النتائج أن أعلى قيم معنوية لطول الساق وقطره (سم) وكذلك وزن 100 حبة (بالجرام) ومحصول حبوب الذرة كانت من معاملة الرى الأولى 25–30% مع التغطية بالبلاستيك في كلا الموسمين. أعطت معاملة الري الأولى 25–30% مع التغطية بالبلاستيك و قش الارز أعلى صافى ربح (3726 بالجنية / فدان) يلية (3100 بالجنية / فدان) على التوالى. وأظهرت الدراسة أن رطوبة التربة المتاحة للرى بنسبة 25–30٪ مع التغطية لها دور في زيادة الغلة وصافي العائد من الذرة.