Plant Archives Volume 20 No. 2, 2020 pp. 8635-8644 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

EFFECT OF BLACK POLY ETHYLENE MULCH AND IRRIGATION DEFICIT ON ONION PRODUCTIVITY AND QUALITY AT WEST NORTH COAST IN EGYPT

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Abstract

Two experiments were conducted at Marsa Matrouh Experimental station, Marsa Matrouh governorate (latitude 31° 20' N and longitude extends about 600 km from Alexandria in the east at 29° 50' E to El-Salloum on the Libyan border in the west at 25°10' during two consecutive seasons (2018-2019 and 2019-2020). The aim of the currentstudy was to investigate the effect of different irrigation rates (T1, T2, T3, T4 and T5) according to 20, 40, 60, 80 and 100 percent of onion water requirements in addition (T0) rainfed treatment as a control. Irrigation treatments were assessed with soil mulching and non-mulching treatments. Results showed that, onion growth, yield and its characters significantly affected by soil mulching and irrigation treatments. The highest onion plant fresh weight and bulb yield were obtained from T4, T5 followed by T3, while T0 then T1 and T2 produced the lowest plant fresh weight and bulb yield. Soil mulching treatment positively affected plant growth and yield compared with bare soil especially in the second season when average seasonal precipitation was limited. Moreover, soil mulching with irrigation treatments deeplyenhanced WUE and IWUE especially in the second season where seasonal precipitation was limited. T1 with soil mulching recorded the highest values of WUE and IWUE (15.2, 26.5 kg/Fed-^{1}/m-^{1}) and (87.8, 124.3 kg/Fed-^{1}/m-^{1}) in two seasons respectively. On the other hand, T5 with bare soil recorded the lowest WUE and IWUE values of (9.8, 17.1 kg/Fed-^{1}/m-^{1}) and (6.3, 16.4 kg/Fed-^{1}/m-^{1}) in first and second season respectively. Our study recommended that, under north eastern Mediterranean coast, sufficient onion yield can be achieved with soil mulching even ifirrigation water deficit within 50 to 60 percent of onion water requirements especially throughout heavy rain seasons. Investment ratio calculations led to conclude thatit can be recommend that, under Marsa Matrouh region conditions, the necessity of using black plastic mulch combined with 40–60 percent of water requirements as a supplemental irrigation is required for onion production to save water as well as to achieve high return.

Key wards: Onion, rainfed, soil mulching, irrigation water deficit, onion yield, wue and investment ratio

Introduction

Onion (*Allium cepa* L.) is a third important vegetable crop in Egypt. It's ranked after potatoes and tomatoes in terms of harvested area by about 81517 ha. Onion is extensively used as fresh or an indispensable component of the Egyptian food by rich and poor all over the year. Although, Egyptian onion production and consumption has been sharply increased in the last decade, where planted area increased by fold (FAOSTAT, 2018) and areashas distributed at both Nail Valley and newly reclaimed lands, local production does not achieves the annual requirements especially inan export seasons.Onion require frequently irrigation because its roots extract most of water from the top 12 inches of soil and keeping adequate soil moisture at upper surface is very important (Anisuzzaman, *et al.,* 2009). Moreover, onion is highly sensitive to water stress under various climate conditions (Pejec *et al.,* 2014) and irrigation at 50 and 75 percent of weekly reference evapotranspiration give the highest water productivity of onion, though onion yield reduced by about 50, 15.5 to 23.0 and 10 percent when 25, 50 and 75 percent of weekly reference evapotranspiration were used (Igbadun *et al.,* 2012). Although, decreasing of onion productivity caused by deficit irrigation show evident reduction flexibility more than any winter vegetable which in turn, possibility obtaining a satisfactory yield under rainfed conditions, where, onion yield can be ranged from five to forty ton per hectare (Pejic, *et al.,* 2011). Onion bulb weight, plant height and quality significantly affected by different water application schedule (Shaibu, *et al.,* 2015).

Egypt falls within Africa's dry desert region except for a narrow strip of land in the north which has a Mediterranean type of climate with an annual average rainfall ranging from 90 to 290 mm (Ali, 1982) or 79 to 200 mm as a recent documentation (FAOSTAT, 2018) along the narrow Mediterranean coast, starting with October by about 10 percent followed by November to March by about 75 percent of annual precipitation. But in this area irrigation water shortage and insufficient precipitation cannot establish cultivation except some cereal crops and some olive and fig orchards (Moustafa, 1986), as well as some vegetables which depending on the amount of rainfall like watermelon, onion, broad beans and tomato (Moustafa and El-Mowelhi, 1999). Thus, using agricultural practices or black polyethylene mulch as a cheap water-saving system, has been developed to drastically increase the precipitation use efficiency in rainfed farming systems in arid and semiarid areas worldwide (Gan *et al.,* 2013; Li *et al.,* 2013). In addition that, polyethylene black plastic mulch are in general, widely used in agriculture due to the countless advantages they have like, create congenial condition for the growth and moderate soil temperature (Moreno *et al.,* 2017; Lal Bhardwaj, 2013; Wang *et al.,* 2016), reduce water evaporationof soil surface(Prosdocimi *et al.,* 2016; Zribi *et al.,* 2015), increasing soil moisture (Li *et al.,* 2007, 2013; Liu *et al.,* 2014; Wang *et al.,* 2016), prolonging the period of soil water availability to plants, penetrating little rain water in to deep soil (Zhang *et al.,* 2007; Qin *et al.,* 2014) and infestation of annual weeds(Lamont, 1993). Polyethylene black plastic mulch can successfully used for almost vegetables crops (Edwards *et al.,* 2000; Lamont, 2017; Moreno and Moreno, 2008). Mulchinghas being a beneficial effects on plant growth, (Hassan *et al.,* 1994; Lal Bhardwaj *et al.,* 2011; Sarolia and Lal Bhardwaj 2012 and Yamaguchi *et al*., 1996), early yield (Tarara, 2000, Lamont, 2005 and Lamont, 2017), increasing productivity (Wang *et al.,* 2017; Zhang *et al.,* 2018) and enhancing fruits quality (Lamont, 2017). The most beneficial mulching effects is water saving and reduce water consumption to relieve water demand. In this respect, water saving cultivation techniques and some rain-water harvesting systems depending on plastic film mulching has promising especially in semi-arid region (Li, *et al.,* 2016). Black plastic film mulching as a rain-water harvesting system has been used in rainfed arid and semi-arid areas to reduce irrigation water amounts, increase water use efficiency and increase total yield compared with non-mulching (Gan *et al.,* 2013; Li *et al.,* 2017; Wang *et al.,* 2016).

In order to maximize irrigation water use and increase crop water productivity especially with irrigation water scarcity and decreasing availability of irrigable agricultural landcombined with unpredictable and limited precipitation, which has become more serious with global climate change and therebygreat negative effects on agricultural production (Piao *et al.,* 2010) which in turn, irrigation schedule of onion has to be adjusted to climatic conditions (Pejic, *et al.,* 2011). So, the objective of our study was trying to increase effective use of precipitation, reduce water consumptionand enhance water use efficiency during winter season by soil mulching with black polyethylene to relieve irrigation water demand in our limited resources and producing highest sustainable onion yield under Northeastern Mediterranean Coast of Egypt.

Materials and Methods

The experiment was conducted at the experimental farm of Marsa Matrouh Research Station, Desert Research Center at Marsa Matrouh governorate during two consecutive winter seasons of 2018-2019 and 2019 -2020. Marsa Matrouh governorate (latitude 31°20'N) is situated inon Egypt northwest Mediterranean coast which extendsabout 600 km from Alexandria in the east at longitude 29°50'E to El-Salloum on the Libyan border inthe west at longitude 25°10' to study the effect of soil mulching treatment (Black plastic poly ethylene 50 micron thickness) which assessed directly before onion transplanting, in addition without soil mulching treatment as a control. To characterize the climate of the experimental area, data gathered by a meteorological station at Marsa Matrouh Research Station (EM50G-Data Loger), then reference crop evapotranspiration (ET_0) was calculated daily by the Penman-Monteith equation (FAO 56 method, Allen *et al.,* 1998) using INSTAT V3.37 program and average week of crop evapotranspiration was estimated. Et_c (actual evapotranspiration) was obtained by $Et_c = Et_0 * K_c$. Then weekly irrigation water requirementswere calculated by the equation:

$$\text{WR (m}^3\text{/day)} = \frac{Et_c + LR + R + A}{1000}$$

Where: WR = waterrequirement, LR = leeching requirement (1.25), R = reduction factor (0.25 - 0.9) A = irrigated area (21 meter).

Then weekly precipitation amounts were minuses before additions.

Lengths of onion growing stages were 15, 25, 70 and 40 days for initial, development, mid and late stages respectively and $k_c$coefficient for onion values were 0.7, 1.05 and 0.75 for initial, mid and late stages (Allen, *et al.,* 1998), While, K_c coefficient during the initial and mid- season stages are constant and equal to the stander K_c

Table 1: Average weekly Kc, Et_0, Et_c, LR%, R, Wr, P and IT for 21 square meter (two plots) of irrigation treatments lines at different onion stages in (2018-2019).

	Kc	Et_0	Et_c ($Kc*Et_0$)	LR %	R %	A (m^2)	Wr (m^2)	P (mm)	P (m^3/ $21m^2$)	(Wr-P) m^3	IT (mints)
Initial stag (11/11-25	0.70	3.27	2.289	1.25	0.25	21	0.034	25.75	0.541	0.00	0.00
/11/2018) (2 weeks)	0.70	3.52	2.464	1.25	0.25	21	0.037	2.50	0.053	0.00	0.00
Development	0.700	2.66	1.995	1.25	0.50	21	0.059	28.75	0.604	0.00	0.00
stage (26/11-	0.750	3.17	2.657	1.25	0.50	21	0.079	1.00	0.021	0.058	12.61
24/12/2018)	0.838	3.24	2.997	1.25	0.50	21	0.089	3.00	0.063	0.026	5.65
(4 weeks)	0.925	2.75	2.888	1.25	0.50	21	0.086	29.50	0.620	0.00	0.00
Mid stage	1.05	2.40	2.520	1.25	0.60	21	0.090	5.50	0.116	0.00	0.00
(25/12-	1.05	2.74	2.877	1.25	0.60	21	0.103	14.00	0.294	0.00	0.00
4/3/2019)	1.05	3.54	3.717	1.25	0.60	21	0.133	1.00	0.021	0.112	24.35
(10 weeks)	1.05	3.28	3.444	1.25	0.60	21	0.123	0.00	0.00	0.123	26.74
	1.05	4.19	4.400	1.25	0.70	21	0.183	1.00	0.021	0.162	35.22
	1.05	3.32	3.486	1.25	0.70	21	0.145	0.00	0.00	0.145	31.52
	1.05	2.89	3.034	1.25	0.70	21	0.126	0.00	0.00	0.126	27.39
	1.05	2.38	2.499	1.25	0.70	21	0.104	10.75	0.226	0.00	0.00
	1.05	3.81	4.001	1.25	0.80	21	0.191	8.00	0.168	0.023	5.00
	1.05	2.94	2.987	1.25	0.80	21	0.142	8.00	0.168	0.00	0.00
Late stage	1.016	3.91	3.378	1.25	0.80	21	0.161	0.00	0.00	0.161	35.00
(5/3-9/4/	0.956	3.62	3.244	1.25	0.80	21	0.155	2.00	0.042	0.150	32.61
2019)	0.896	4.70	3.929	1.25	0.90	21	0.211	0.00	0.00	0.211	45.87
(5 weeks)	0.836	3.45	2.677	1.25	0.90	21	0.143	14.50	0.301	0.00	0.00
	0.776	4.51	3.510	1.25	0.90	21	0.188	0.00	0.00	0.188	40.87

Table 2: Average weekly Kc, Et_0, Et_c, LR%, R, Wr, P and IT for 21 square meter (two plots) of irrigation treatments lines at different onion stages in (2019-2020).

	Kc	Et_0	Et_c ($Kc*Et_0$)	LR %	R %	A (m^2)	Wr (m^2)	P (mm)	P (m^3/ $21m^2$)	(Wr-P) m^3	IT (mints)
Initial stag (27/10-9	0.70	3.96	2.772	1.25	0.25	21	0.041	0.00	0.00	0.041	8.91
/11/2019) (2 weeks)	0.70	2.75	1.952	1.25	0.25	21	0.029	0.00	0.00	0.029	6.30
Development	0.70	3.51	2.457	1.25	0.50	21	0.073	0.00	0.00	0.073	15.87
stage (10/11-	0.750	2.97	2.228	1.25	0.50	21	0.066	0.00	0.00	0.066	14.35
7/12/2019)	0.838	3.79	3.176	1.25	0.50	21	0.095	0.00	0.00	0.095	20.64
(4 weeks)	0.925	3.09	2.858	1.25	0.50	21	0.085	0.00	0.00	0.085	18.48
Mid stage	1.05	3.68	3.864	1.25	0.60	21	0.138	11.75	0.247	0.000	0.00
(8/12-	1.05	2.15	2.258	1.25	0.60	21	0.081	0.25	0.00	0.076	16.52
15/2/2020)	1.05	3.66	3.843	1.25	0.60	21	0.137	15.75	0.331	0.000	0.00
(10 weeks)	1.05	2.50	2.625	1.25	0.60	21	0.094	9.00	0.189	0.000	0.00
	1.05	2.57	2.699	1.25	0.70	21	0.112	6.25	0.131	0.000	0.00
	1.05	2.09	2.195	1.25	0.70	21	0.091	6.75	0.142	0.000	0.00
	1.05	3.52	3.696	1.25	0.70	21	0.154	2.00	0.042	0.112	24.35
	1.05	2.54	2.667	1.25	0.70	21	0.111	0.00	0.000	0.111	24.13
	1.05	3.66	3.843	1.25	0.80	21	0.183	3.50	0.074	0.109	23.70
	1.05	3.06	3.213	1.25	0.80	21	0.153	0.00	0.00	0.153	33.26
Late stage	1.016	3.57	3.627	1.25	0.80	21	0.173	1.25	0.026	0.147	31.96
(16/2-21/3/	0.956	3.71	3.547	1.25	0.80	21	0.169	11.50	0.242	0.00	0.00
2020)	0.896	3.95	3.539	1.25	0.90	21	0.190	0.75	0.016	0.174	37.83
(5 weeks)	0.836	3.43	2.867	1.25	0.90	21	0.154	18.75	0.394	0.00	0.00
	0.776	4.09	3.174	1.25	0.90	21	0.170	0.00	0.00	0.170	36.96

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

Soil depth (cm)	Texture class	Soluble anions (me/l)			pHsoil paste	E.C dSm^{-1}	Soluble cations (me/l)			
		HCO_3^-	$SO_4^=$	Cl^-			Ca^{++}	Mg^{++}	Na^+	K^+
0 – 25	Sandy loam	0.75	0.85	4.25	7.6	4.15	2.25	.840	3.92	0.32

PH: Acidity E.C.: Electrical conductivity me/l: milli equivalent per liter.

value of the growthstage, crop development and late season stages valuesvarieslinearly between the K_c at the end of the previous stage (K_c prev) and the K_c at the beginningof the next stage (K_c next), which is K_c end in the case of the late season stage (FAO 56 method, Allen *et al.,* 1998).

$$K_{ci} = \frac{K_{c\,prev} + \left[\left(i - \sum\left(L_{prev}\right)\right)\right]\left(K_{c\,next} - K_{c\,prev}\right)}{L_{stage}}$$

Where: iday number within the growing season [1... length of the growing season]

K_c i crop coefficient on day i

Table 4: Effect of black poly ethylene mulch and irrigation deficit on total weeds count and fresh weight.

Parameters / Seasons / Treatments		Total weeds count 1St	Total weeds count 2nd	Total weeds fresh weight (g) 1St	Total weeds fresh weight (g) 2nd
Soil Mulching					
With mulching		14.1	13.9	42.1	143.4
Without mulching		150.7	129.0	613.9	836.6
LSD at 0.05		10.5	4.2	19.2	46.8
Irrigation treatments					
Rain-fed (without irrigation)		84.1	70.8	220.2	515.0
20 % of WR		84.5	69.7	297.5	482.2
40 % of WR		91.2	74.0	336.7	498.8
60 % of WR		78.8	72.3	360.5	504.8
80 % of WR		79.7	70.3	368.3	476.8
100 % of WR		76.2	71.7	384.7	462.2
LSD at 0.05		N.S	N.S	49.7	N.S
Interaction Mulching X Irrigation treatments.					
Mulch.	Rain-fed	13.5	14.0	41.3	136.3
	20 % of WR	14.7	13.3	43.3	138.3
	40 % of WR	17.3	14.3	46.7	144.7
	60 % of WR	13.3	14.3	41.0	157.3
	80 % of WR	13.0	14.0	39.0	143.0
	100 % of WR	12.7	13.7	41.0	140.7
Without	Rain-fed	154.7	127.7	399.0	893.7
	20 % of WR	154.3	126.0	551.7	826.0
	40 % of WR	165.0	133.7	626.7	853.0
	60 % of WR	144.3	130.3	680.0	852.3
	80 % of WR	146.3	126.7	697.7	810.7
	100 % of WR	139.7	129.7	728.3	783.7
LSD at 0.05		N.S	N.S	70.3	N.S

L_{stage} length of the stage under consideration [days]

$S(L_{prev})$ sum of the lengths of all previous stages [days]

Five irrigation treatments (T1, T2, T3, T4 and T5) according to 20, 40, 60, 80 and 100 percent of onion water requirement (WR), in addition to rainfed treatment as a control (T0) were concluded. All values of average weekly K_c (onion coefficient), Et_0(reference crop evapotranspiration), Et_c(Actual evapotranspiration), LR% (leaching requirements), R % (reduction factor), Wr (water requirements), P(precipitation) and IT (irrigation time) for 21 square meter of irrigation treatments lines atdifferent onion stages in(2018-2019, 2019-2020) were calculated and presented in tables 1 and 2.

Irrigation time was calculated for every twenty one meter (irrigation treatment which contain mulched and non–mulched plotsas the equation:

Irrigation time =

$$\frac{Water\ requirement\,(Liters)}{Water\ flowing\ by\ all\ emitters\,(M\,\text{int}\,s)}$$

Where, water flowing by mints = number of emitters (69) × emitter water flowing in mint (66.7 ml) = 4.6 liter/ mint.

It may be worth to mention that, the experimental site have additionalparallel lines to maintain constant pressure to ensure steady flowing. Where, just a treatment lines has closed, the parallel lines opened. Water use efficiency (WUE) and irrigation water use efficiency (IWUE) were estimated as follow: WUE = total yield (kg)/water amount (m^3), IWUE = $(Y_{irr} – Y_{dry})/I$, where, Y_{irr} is the bulb yield of irrigated plots, Y_{dry} is the bulb yield of non-mulching and non-irrigated plots, I is the irrigation water used. WUE and IWUE were estimated as (Kadayifci *et al.,* 2005).

Physical and chemical characters of experimental soil and irrigation water properties are shown in table 3 and 4. The experiment was arranged in a split plot design, where soil mulching were assessed in main plot, while the irrigation treatments assessed in sub-plot in 3 replicates.

Experimental plots were consisted of oneline, each of one meter wide and 10.5 meter long. Recommended cultural practices, *i.e.*, fertilization, disease and pest control were applied. Onion transplants of Giza9 cultivar hand transplanting directly after mulching which in turn has occurred when soil watered by first autumn rain. Plant spacing was 10×14.3 cm to give about 42 plants per square meter.A random sample of 10 plants of each experimental plot were taken at 60 days after transplanting for vegetative growth datavs plant height, leaves number and plant fresh weight. One quadratic meter randomly was taken after 4 weeks from transplanting to determine, average number and total fresh weight of both broad and narrow-leaved weeds. At harvest time (Med of April) one quadratic meter was taken from each plot to determine total weight of bulbs, bulb diameter, nick diameter and total yield per feddan were calculated. Water use efficiency was calculated using total water (precipitation plus irrigation, WUE) and using only irrigation water (IWUE) by dividing the economic yield by the amount of used water. Investment ratio was also calculated according to Rana *et al.,* (1996). Investment ratio (IR) = Total output LE/Total costs LE. Data were subjected to statistical analysis by M-STAT C (Russel, 1991). The differences among means were performed using least significant difference (LSD) at 5% level.

Results and Discussion

Weed control: Data in table 4 showed that, mulching treatment had a significant effect in terms of total weeds count and its total fresh weight in both seasons compared with non-mulching treatment. On the other hand, irrigation treatment and interaction with mulching had not a significant effects on weed characters except, total weed fresh weight in the first season, since, the rainfed treatment produced the lowest value followed by T1 (20% of daily WR) especially with absence of soil mulching compared with other irrigation treatments. This results was expected and agree with (Lamont, 1993), whose reported that, black plastic reduce light penetration into the soil and consequently weeds generally cannot survive under the mulch. Especial case in our study that, weeds growing under mulching treatments are in disagreement with most research studies on other crops because malty spores occurred in plastic sheet allowed to weed seeds germinate and growing throw this spores. Similar results were found by (Hafez and Gomaa, 2018).

Vegetative growth: Soil mulching significantly increased plant height, leaves number and plant fresh weight seventy days after transplanting compared with non-mulching treatment in both seasons, except leaves number in the first season, table 5. In general, the superiority of mulching treatment was most pronounced in the second season compared with the first one. The same trend was evident with irrigation treatments, since T5 and T6 followed by T4 produced the highest and heaviest onion plants in the second season compared with other treatments especially T0 (rain-fed) treatment. While, there were not significant differences between irrigation treatments in the first season. Concerning interaction effect, there was not significant effects on plant height, leaves number and plant fresh weight in both season, only plant height in the second

Table 5: Effect of black poly ethylene mulch and irrigation deficit on plant height, leaves number and plant fresh weight.

Parameters		**Plant height (cm)**		**Leaves Number**		**Plant fresh weight (g/plant)**	
Seasons / **Treatments**		**1St**	**2nd**	**1St**	**2nd**	**1St**	**2nd**
Soil Mulching							
With mulching		36.25	38.96	6.99	6.90	61.53	66.98
Without mulching		32.90	33.69	6.99	6.43	50.96	52.99
LSD at 0.05		3.09	1.12	N.S	0.43	3.18	4.32
Irrigation treatments							
Rain-fed (without irrigation)		33.15	31.14	6.80	5.85	54.83	51.09
20 % of WR		35.05	35.38	6.93	6.19	54.84	53.53
40 % of WR		34.12	36.47	6.95	6.64	55.83	57.95
60 % of WR		35.05	37.62	6.99	6.71	56.50	63.87
80 % of WR		35.39	38.52	7.11	7.31	57.24	67.20
100 % of WR		34.72	38.83	7.15	7.30	58.24	66.27
LSD at 0.05		N.S	0.89	0.13	0.27	N.S	3.87
Interaction Mulching X Irrigation treatments.							
Mulch.	Rain-fed	34.96	34.63	6.89	6.21	60.55	57.39
	20 % of WR	35.67	36.67	6.84	6.46	60.65	59.05
	40 % of WR	36.65	39.32	6.88	6.78	62.40	68.18
	60 % of WR	36.46	40.79	7.04	6.94	62.06	71.10
	80 % of WR	37.41	41.68	7.12	7.57	61.35	72.97
	100 % of WR	36.36	40.69	7.18	7.46	62.20	73.19
Without	Rain-fed	31.35	27.64	6.70	5.49	49.10	44.79
	20 % of WR	34.43	34.10	7.01	5.93	49.03	48.01
	40 % of WR	31.58	33.61	7.03	6.51	49.26	47.71
	60 % of WR	33.64	34.45	6.94	6.48	50.94	56.63
	80 % of WR	33.36	35.36	7.11	7.04	53.13	61.43
	100 % of WR	33.08	36.97	7.13	7.13	54.27	59.35
LSD at 0.05		N.S	1.25	N.S	N.S	N.S	N.S

season was significant. The most evident effect was decreasing plant height when onion transplanting on bare soil with rain-fed treatment compared with other treatments especially soil mulching with T4, T5 and T6. Many researchers has being reported that, mulchinghas being a beneficial effects on plant growth, (Hassan *et al.,* 1994; Lal Bhardwaj *et al.,* 2011; Sarolia and Lal Bhardwaj 2012 and Yamaguchi *et al*., 1996). Moreover, (Igbadun *et al.,* 2012; Pejic, *et al.,* 2011; Shaibu, *et al.,* 2015) found that, onion growth characters significantly affected by different water application schedule.

Yield and its component: The effect of soil mulching, irrigation water rates and their interactionson onion yield per feddan, average bulb weight, bulb diameter and nick diameter are shown in table 6. Soil mulching increased onion yield, average bulb weight, bulb diameter and nick diameter compared with non-mulching treatment in both season. The increasing was relatively clear in the second season. Regarding irrigation water treatments, T0 (rainfed) treatment significantly produced the lowest yield characters compared with irrigation treatments, followed by T1 (20 % of daily WR) then T2 in the second season. While in the first season, rainfed was produced the lowest values compared with all irrigation treatments.In this respect, T2, T3, T4 and T5 produced the highest significant yield in the first season, while T4 and T5 followed by T3 gave the highest significant yield in the second season. Also, the different between treatments was evident in the second season compared with first one. Most of interaction effects were not significant except yield and bulb diameter in the second season, since T4 (80% of daily WR) gave the highest yield followed by T5 (100% of WR) with soil mulching compared with T0 (rainfed) with non-mulching treatment which produced the lowest values followed by T1, T2 and T3 with non-mulching treatment. The superiority of mulching treatment and its positive effect on onion yield was expected as we has noticed from previous study conducted at Siwa oasis by Hafez and Gomaa, (2018). Moreover, our results are agree with (Moreno *et al.,* 2017; Lal Bhardwaj, 2013; Wang *et al.,* 2016) and many researchers in this respect who reprted that, mulching inhancement may refers to create congenial condition for the growth and moderate soil temperature, reduce water evaporationof soil surface, increasing soil moisture, prolonging the period of soil water availability to plants and infestation of annual weeds.In the same time, mulchinghave being a beneficial effectson water saving and reduce water consumption as a cultivation technique and rain-water harvesting system especially in semi-arid region (Li, *et al.,* 2016) and consequently led to reduce irrigation water amounts (Gan *et al.,* 2013; Li *et al.,* 2017; Wang *et al.,* 2016) especially in rainy seasons. Under our area conditions, with high or moderate average seasonal precipitation using 40 percent of daily WR was sufficient to produce maximum onion yield, while with limited precipitation using 80 percent of daily WR are recommended. Similar results on onion were reported by (Igbadun *et al.,* 2012; Pejic, *et al.,* 2011; Pejec *et al.,* 2014 and Shaibu, *et al.,* 2015).

Table 6: Effect of black poly ethylene mulch and irrigation deficit on onion yield, average bulb weight, bulb diameter and nick diameter.

Parameters / Seasons / Treatments		Yield (kg/fed dan) 1St	Yield (kg/fed dan) 2nd	Average bulb weight (g) 1St	Average bulb weight (g) 2nd	Bulb diameter (cm) 1St	Bulb diameter (cm) 2nd	Nick diameter (cm) 1St	Nick diameter (cm) 2nd
Soil Mulching									
With mulching		10526	11225	94.43	95.45	7.82	7.91	2.02	1.78
Without mulching		7813	8171	68.52	70.71	7.18	7.11	1.71	1.65
LSD at 0.05		878	802	18.86	3.92	0.57	0.12	0.11	0.07
Irrigation treatments									
Rain-fed (without irrigation)		8069	7603	80.33	68.34	6.62	6.64	1.69	1.50
20 % of WR		9004	9208	80.34	78.30	7.13	7.19	1.81	1.58
40 % of WR		9231	9664	80.67	82.17	7.56	7.36	1.89	1.71
60 % of WR		9552	10315	82.17	87.71	7.78	7.68	1.97	1.76
80 % of WR		9504	10734	82.26	91.28	7.90	8.08	1.88	1.86
100 % of WR		9658	10664	83.07	90.68	7.99	8.12	1.98	1.87
LSD at 0.05		635	362	N.S	5.05	0.24	0.11	0.15	0.09
Interaction Mulching X Irrigation treatments									
Mulch.	Rain-fed	9046	8810	93.55	74.91	7.05	7.20	1.76	1.57
	20 % of WR	10569	10665	93.65	90.69	7.67	7.77	2.06	1.62
	40 % of WR	10774	11099	94.07	94.38	7.73	7.93	1.99	1.82
	60 % of WR	10918	11934	94.73	101.48	7.96	8.07	2.08	1.81
	80 % of WR	10873	12718	95.36	108.15	8.19	8.23	2.11	1.91
	100 % of WR	10973	12120	95.20	103.06	8.29	8.23	2.15	1.93
Without	Rain-fed	7091	6397	67.10	61.77	6.19	6.07	1.61	1.42
	20 % of WR	7439	7751	67.03	65.91	6.59	6.60	1.56	1.55
	40 % of WR	7687	8229	67.26	69.97	7.39	6.80	1.78	1.59
	60 % of WR	8185	8695	69.60	73.94	7.60	7.29	1.86	1.71
	80 % of WR	8134	8750	69.17	74.40	7.61	7.93	1.66	1.81
	100 % of WR	8342	9207	70.93	78.29	7.70	8.00	1.80	1.82
LSD at 0.05		N.S	512	N.S	N.S	N.S	0.16	N.S	N.S

Table 7: Effect of black poly ethylene mulch and irrigation deficit on onion yield, wue and iwue.

Parameters / Seasons / Treatments		Yield (kg/fed.) 1St	Yield (kg/fed.) 2nd	Precipitation (m³/fed.) 1St	Precipitation (m³/fed.) 2nd	Irrigation (m³/fed.) 1St	Irrigation (m³/fed.) 2nd	Total water (m³) 1St	Total water (m³) 2nd	WUE (Kg/m³) 1St	WUE (Kg/m³) 2nd	IWUE (kg/m³) 1St	IWUE (kg/m³) 2nd
Mulch.	Rain-fed	9046	8810	656.6	367.8	0.0	0.0	656.6	367.8	13.8	24.0	0.0	0.0
	20 % of WR	10569	10665	656.6	367.8	39.6	34.3	696.2	402.1	15.2	26.5	87.8	124.3
	40 % of WR	10774	11099	656.6	367.8	79.2	68.7	735.8	436.5	14.6	25.4	46.5	68.5
	60 % of WR	10918	11934	656.6	367.8	118.8	103.0	775.4	470.8	14.1	25.3	32.2	53.7
	80 % of WR	10873	12718	656.6	367.8	158.4	137.4	815.0	505.2	13.3	25.2	23.9	46.0
	100 % of WR	10973	12120	656.6	367.8	198.0	171.7	854.6	539.5	12.8	22.5	19.6	33.3
Without	Rain-fed	7091	6397	656.6	367.8	0.0	0.0	656.6	367.8	10.8	17.4	0.0	0.0
	20 % of WR	7439	7751	656.6	367.8	39.6	34.3	696.2	402.1	10.7	19.3	8.8	39.4
	40 % of WR	7687	8229	656.6	367.8	79.2	68.7	735.8	436.5	10.4	18.9	7.5	26.7
	60 % of WR	8185	8695	656.6	367.8	118.8	103.0	775.4	470.8	10.6	18.5	9.2	22.3
	80 % of WR	8134	8750	656.6	367.8	158.4	137.4	815.0	505.2	10.0	17.3	6.6	17.1
	100 % of WR	8342	9207	656.6	367.8	198.0	171.7	854.6	539.5	9.8	17.1	6.3	16.4

Table 8: Fixed and variable inputs and output for onion production under Northeastern Mediterranean coast at MarsaMatrouh region (LE/fed.).

Items	Total LE	Unit coast	Co-unts	Unit
Fixed cost/ fed				
Land preparation	600	150	4	Hour
Organic fertilizer	4800	160	30	m³
Chemical fertilizers:				
1- mono super phosphate	600	2	300	kg
2- ammonium sulfate	600	3	200	kg
3- ammonium nitrate	600	6	100	kg
4- potassium sulfate	1500	10	150	kg
Onion transplants	2400	120	20	12.6 (m²)
Labor cost:				Workers /day
1- fertilizer add	600	150	150	4
2- Transplanting	1800	150	150	12
3- Seasonal labor	1200	80	80	15
4- Harvest labor	750	150	150	5
Pesticides	750	150	5	Liter
Foliar fertilizers	400	80	5	Liter
Total	15850			
Variable cost (additional				
cost for our treatments)				
Black plastic mulch/ fed.	1500	30	50	kg
Water cost (m³)		11	1	m³
Output (onion yield /fed.): Onion yield		2100 LE st and 2500 nd.	1	Ton/fed.

Table 9: Gross input of onion (LE/fed.) in 2018/2019 and 2019/2020 seasons.

Water application cost: Water treatments	Water add	Cost Le/fed	Mulching application: With (1500 LE)	Mulching application: Without (0 LE)	Fixed cost (LE /fed)
		2019 season			
Rain fed	0	0	17350	15850	15850
20% of WR	39.6	435.6	17786	16286	15850
40% of WR	79.2	871.2	18221	6721	15850
60% of WR	118.8	1306.8	18657	17157	15850
80% of WR	158.4	1742.4	19092	17592	15850
100% of WR	198.0	2178	19528	18028	15850
		2020 season			
Rain fed	0	0	17350	15850	15850
20% of WR	34.3	377.3	17727	16227	15850
40% of WR	68.7	755.7	18106	16606	15850
60% of WR	103.0	1133	18483	16983	15850
80% of WR	137.4	1511.4	18861	17361	15850
100% of WR	171.7	1888.7	19239	17739	15850

Water use efficiency (WUE) and irrigation water use efficiency (IWUE)

Water use efficiency (WUE) and irrigation water use efficiency (IWUE) were calculated for each treatment during two growing seasons table 7. The results showed that, T1 (20% of crop water requirement) with soil mulching recorded the highest values of WUE and IWUE (15.20, 26.5 kg/Fed-1/m^{-1}) and (87.8, 124.3 kg/ Fed^{-1}/m^{-1}) in two seasons respectively. On the other hand, T5 (100% of crop water requirement) with bare soilrecorded the lowest WUE and IWUE values of (9.8, 17.1 kg/Fed^{-1}/m^{-1}) and (6.3, 16.4 kg/Fed^{-1}/m^{-1}) in first and second season respectively. In general, soil mulching enhanced WUE and IWUE in both seasons compared with non-mulching treatment and the enhancement was relatively higher in the second season because average seasonal precipitation was limited. Regarding irrigation treatments, both WUE and IWUE sharply decreased with increasing irrigation water amounts. Many researchers

Table 10: Total output and investment ratio (IR) of onion under water deficit and soil mulch treatments.

Treatments		First season		Second season	
Mulch treat-ments	**Water deficit (%of water requirements)**	**Total output (L/E)**	**Inves-tment ratio**	**Total outpur (L/E)**	**Inves-tment ratio**
Mulch	Rain fed	18997	1.095	22025	1.269
	20%	22195	1.249	26663	1.504
	40%	22625	1.242	27748	1.532
	60%	22928	1.229	29835	1.614
	80%	22833	1.196	31795	1.686
	100%	23043	1.100	30300	1.575
Mean		22104	1.206	28060	1.530
Without Mulch	Rain fed	14891	0.939	15993	1.009
	20%	15622	0.959	19278	1.189
	40%	16143	0.965	20573	1.239
	60%	17189	1.002	21738	1.280
	80%	17081	0.971	21875	1.260
	100%	17518	0.966	23018	1.298
Mean		16407	0.967	20429	1.213

have been interesting to determine even WUE and IWUE in order to, enhance crop productivity in the case of limited precipitation or scarcity of irrigable water mostly in arid and semi-arid areas (Kumar *et al.,* 2007; Nazeer and Ali, 2012; Shaibu, *et al.,* 2015). Highest IWUE value was obtained in dry seasons compared with rainy seasons, which clearly decreased the IWUE value and in turn reflected the importance of irrigation water applied especially when limitation of seasonal average precipitation or unequal distribution (Pejic *et al.,* 2011).

Economic studies: The agriculture development is an economic process and the final goal of the present study is to get profitable yield as gain from the invested cost. Tables 8 and 9 showed the calculated input (LE/fed.) and table 10 showed output (LE/fed.) and investment ratio for the investigated treatments. Calculation of investment ratio (IR) shown in table 10 revealed the following facts:

1) Using black plastic mulch gave higher investment ratio (1.206 and 1.530) than that of without mulch which gave 0.967 and 1.213 in the first and second season respectively.Such result led to conclude that the necessity of using soil mulch is required.

2) Investment ratio was increased with increasing irrigation water. It amount to 1.242 and 1.614 with mulch treatment combined with 40 percent and 60 percent of onion water requirements in the first and second seasons respectively, then began to decrease. The corresponding values with bare soil combined with 60 percent treatment were 1.002 and 1.280. Again, the necessity of using soil mulch is required to save water.

3) Rain fed treatment gave very low investment values whether with or without mulch. It gave with mulch treatment 1.095 and 1.269 in the first season respectively. The corresponding valued with bare soil were 0.939 and 1.009. Such result led to concluded that, the necessity of supplementary irrigation was record for onion production under the investigated area.

4) The highest investment values amounted to 1.242 with mulch treatment combined with 40 percent of onion water requirements in the first season, but it was amounted to 1.614 with mulch treatment combined with 60 percent of onion water requirements in the second season. Such result means that, each one thousand LE invested capital (costs) gave profit return 242 and 614 LE in the first and second season, respectively.

Recommendation

It can be recommended that under MarsaMatrouh conditions, the necessity of using black plastic mulch combined with 40-60 percent of water requirements as a supplanted irrigation is required for onion production depending upon rainfall distribution regularity.

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