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EVALUATION OF MULCH TYPES AND IRRIGATION LEVELS ON PRODUCTIVITY AND WATER USE EFFICIENCY OF ONION

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ABSTRACT

The modern method of producing bulb crops uses proper soil cover for weed control and a sufficient amount of irrigation water to increase onion productivity under drip irrigation. The trial was conducted at Dokki Farm, which belongs to CLAC, Agricultural Research Center, El-Giza Governorate, Egypt, during two growing winter seasons in 2019/2020 and 2020/2021. This study looked at the effects of three irrigation levels (50, 75, and 100 percent of irrigation requirement (equal 1571, 2357, and 3143 m^3 water per feddan, respectively as average two seasons)) and four soil cover treatments (black polyethylene, white polyethylene, rice straw mulch, and control (bare soil) on onion crop growth and production over two seasons.

Regardless of mulch type, all soil cover treatments increased soil temperatures compared with control. The application of 100% from irrigation requirement (IR) resulted in a significant increase of the plant length, number of leaves per plant, and fresh revealed that polyethylene mulch, especially black colour, is the most appropriate for producing onion. The soil cover affected the N, P, and K contents of onion plants. The 100% IR and black polyethylene cover gave the highest values of net income, for onion.

The irrigation level is 100 % (3143 m^3 water/feddan as average of two seasons) and black polyethylene is the best condition for high crop yield and quality. While the best conditions for water use sufficiency were obtained under irrigation level 50 % and black mulch.

Key Words: Onion (*Allium cepa* L), water management, irrigation requirement, organic mulch, water use efficiency.

INTRODUCTION

Water is seen as an essential component of farming and the numerous types of crops consumed by people. Humanity has been interested in the efficient use of water in food production for millennia, therefore the ability to grow crops while meeting their water requirements is vital for civilization. Furthermore, irrigated agriculture, which is a major component of farming, can be damaging to the environment and risk sustainability if not properly managed. **(Darwesh *et al*., 2019).**

Deficit irrigation is one way of enhance water use efficiency for higher yields per unit of irrigation water used in agriculture **(Farrag *et al*., 2016).** Deficit irrigation conditions crop is exposed to a water stress either during a particular growth period or throughout the whole growing season **(Abdrabbo *et al*., 2012).** The expectation is that the yield reduction by inducing controlled water stress will be insignificant compared with the benefits gained through diverting the saved water to irrigate an additional cropped area **(Zakher, and Abdrabbo, 2014).**Onion require frequently irrigation because its roots extract most of water from the top thirty centimeter of soil and keeping adequate soil moisture at upper surface is very important **(Anisuzzaman, *et al*., 2009).**The crop requires 350-500mm of water over the growing season; hence, adequate moisture through irrigation is important in the production of onions **(Khokhar, 2018).** Moreover, since onion shows the reduction of both evapotranspiration rate and yield under water deficit, irrigation is necessary to obtain the optimum size and weight of bulbs, especially during the stage of bulb development **(Kadayifci *et al*., 2005).** Furthermore, mulch polyethylene mulch led to increasing water use efficiency for plants **(Abdrabbo *et al*., 2009 and Darwesh *et al*., 2019).**

The degree of contact between the mulch and the soil also affects soil warming. The better contact the mulch has with the soil, the more effective the warming properties of the mulch **(Lamont, 1996)**.In soil management relationships, mulching has been reported to influence organic matter content, the activity of microorganisms, availability of soil nutrients, control of erosion, and soil compaction **(Stowell, 2000)**.Mulching, on the other hand, involves the use of organic or inorganic materials to cover the cropped soil surface. Mulching has the potential of reducing evaporation, conserve soil moisture, modify soil temperature, and improve aeration. Crop residues and grasses are typically organic materials commonly used for mulching, while synthetic materials (e.g. polyethylene sheets of different thicknesses and colours) are typical inorganic materials used for mulching. Research evidence had shown that soil surface evaporation contributes largely to the total evapotranspiration in the cropped field **(Ahmad *et al*., 2007**).

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 rain-fed 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)**.Regarding the high economic value of onion crop in Egypt and usefulness of mulching in enhancing yield, field experiments were conducted to evaluate the effect of different mulching materialsand irrigation levels on the growth, yield and quality of onion.

MATERIALS AND METHODS

This study was carried out in two winter seasons in 2019/2020 and 2020 /2021 under open field condition at Dokki Protected Cultivation Experimental farm, belongs to the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), at Giza Governorate, Egypt to study the effects of three irrigation levels (50, 75, and 100 per cent of irrigation requirement) and four soil cover treatments (black polyethylene, white polyethylene, rice straw mulch, and control (bare soil) on onion crop growth and production over two seasons.

Plant Material: Seedlings of onion (*Allium cepa* L.)Beheri Redcultivar were transplanted on 15th and 13th of November 2019 and 2020, respectively. Beheri Red cultivar is widely used for its highly yielding capacity in the clay soil and exportation bulbs to the European Union Countries.

The Field Experiment:

This experiment included 12 treatments:Three irrigation levels 50, 75 and 100% of irrigation requirements (IR)as main plots and four mulching treatments: Black and white polyethylene as well as mulch by rice straw (RS) mulch, in addition to control treatment (bare soil) as sub-plots. Three replicates were used in this study. The mulch treatments were applied to the soil before cultivating onion seedlings. Black and white polyethylene were laid after the establishment of the double rows (0.80 m width); the bed wasmanually installed to correspond to treatments and experimental field design. The buffer distance between each treatment measured 1 m. For the black and white polyethylene mulch treatments, four circles of about 3 cm diameter(two circles in each sides) were cut around the irrigation emitter points to cultivate the onion seedlings. Two polyethylene laterals were used for irrigating onion for each raised bed. The distance between polyethylene laterals was 0.30 m. The distance between each plant and emitter was 7.5 cm. The distance between every two emitters was 0.30 m (Figure 1).Rice straw mulch treatment was carried out by covering the soil by about ten centimeters of rice straw afterbeds were established with about 5 cm height.

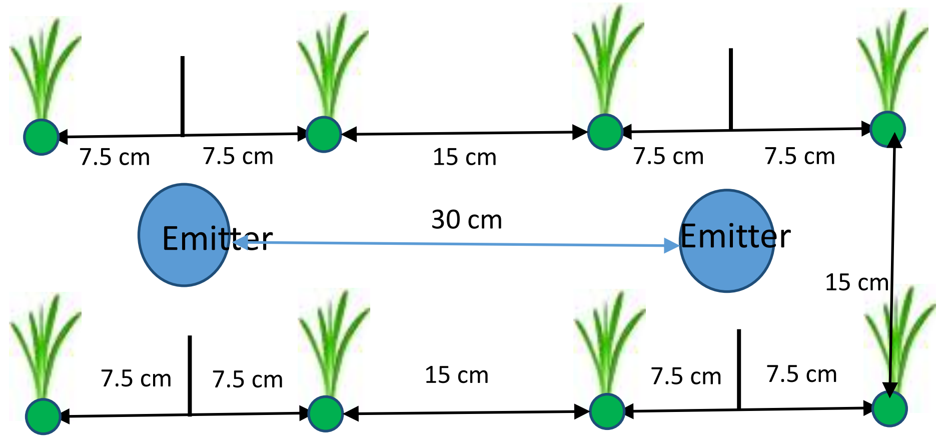

Fig. 1: Layout of the field experiment shows the in-row plant distances.

The plot area was 10 m (length) x 2.8 m (width). The physical and chemical characteristics of the experimental soil are presented in Table 1. The chemical and physical properties of the clay experimental soil were determined before cultivation **(Chapman and Pratt, 1961).** The saturation point % (SP), field capacity % (FC), wilting point % (WP), and bulk density g/ cm^3 (BD) of the soil were determined according to **Israelsen and Hansen (1962).**

Table (1): Chemical and physical analyses of the soil at the experimental site.

Soil depth	Chemical properties							
	ECe mmohs	pH	Ca^{++} mg/L	Mg^{++} mg/L	Na^{+} mg/L	K^{+} mg/L	HCO_3^{-} mg/L	CL^{-} mg/L
0 – 30 cm	2.82	7.65	4.95	1.66	8.66	5.16	3.05	10.85
	Physical properties							
	Sand (%)	Clay (%)	Silt (%)	Texture	SP (%)	FC (%)	WP (%)	BD g/ cm^3
	10.4	82.4	7.2	Clay	23.4	33.1	15.5	1.21

Efficiency of water use and irrigation application

In the crop coefficient approach the crop evapotranspiration (ETc) is calculated by multiplying the reference crop evapotranspiration (ETo) by a crop coefficient (Kc) according to **FAO, (1998):**

IR = ETo * Kc * LR * 4.2/Ea

Where: -

IR = Irrigation requirement for crop (m^3Feddan^{-1} day^{-1})

Kc = Crop coefficient (dimensionless).

ETo = Reference crop evapotranspiration (mm day^{-1}).

LR = Leaching requirement (%), assumed 20% of the total applied water.

Ea = Efficiency of the irrigation system, assumed 85% of the total applied water.

4.2 = to convert IR from mm day^{-1} to m^3Feddan^{-1} day^{-1} (Feddan = 4200 m^2).

The water use efficiency (WUE) was calculated according to **FAO (1982)** as follows:

The ratio of crop yield (y) to the total amount of irrigation water use in the field for the growth season (IR); WUE (Kg /m^3) = Y (kg)/IR (m^3). The average weekly irrigation requirements (m^3feddan^{-1}) under different irrigation levels for onion during the two studied seasons are represented in Table (2). The treatment irrigation was applied after two weeks from planting.

Treatments were as follows:-

Data recorded: -

1) **- Vegetative growth characteristics:** Three plants of each experimental plot were taken after 90 days from the transplanting date to determine growth parameters. The following data were recorded, i.e. plant height (cm), number of leaves per plant, fresh weight of leaves (g/ plant), and dry weight of onion leaves were taken after dried in an electric oven to constant weight at 70° C.
2) **–Yield component and total yield**: All the plants of every plot of the experiment were harvested at 140 days from transplanting and the data were recorded(average neck diameter(cm), bulb diameter (cm), bulb length (cm), Bulb weight (g/ bulb) and the total & marketable yield (ton per feddan)was derived from the total yield of the experimental plots. **Abo-Dahab. *et al*., (2016)** reported that unmarketable yield (t/fed.): includes bulbs of less than 3 cm diameter, doubles, scallions.(feddan= 4200m^2=0.42 hectar)
3) **- Chemical content:** Three plant samples of each plot were dried at 70°C in an air forced oven for 48 h. Dried leaves were digested in H_2SO_4**.** N, P, and K percentages were estimated in the acid digested solution by colorimetric method (Ammonium molybdate) using spectrophotometer and flame photometer (**Chapman and Pratt, 1961**). Total nitrogen was determined by the Kjeldahl method according to the procedure described by **FAO (1980).** Phosphorus

content was determined using a spectrophotometer according to **Watanabe and Olsen (1965).** Potassium content was determined photo-metrically using a Flame photometer as described by **Chapman and Pratt (1961)**. A soluble solid content (TSS) was determined by using a digital refractmeter (Abbe Leica model).Free proline was extracted and measured in mg per g of leaf dry weight in 0.5 g dried leaf tissue according to **Bates *et al.* (1973).** Samples were ground in 10 ml of sulphosalicylic acid 3% (v/v), and the obtained mixture was then centrifuged at 10,000 × g for ten minutes in a proper test tube. 2-ml of freshly prepared ninhydrin acid solution was added to 2 ml of the supernatant. The tube was incubated in a water bath at 90ºC for 30 minutes, and the reaction was terminated in an ice bath. The reaction mixture was then extracted with 5 ml of toluene and vortex-mixed for 15 seconds. At room temperature, the tube was allowed to stand for at least 20 minutes in the dark to separate the toluene and aqueous phases. The toluene phase was then collected carefully into a proper test tube. The absorbance of the toluene phase was read at 520 nm, and the concentration of proline was determined from a standard curve prepared using analytical grade proline and expressed as mg per gram of leaf dry weight.

4)– Climatic data: the maximum and minimum temperature, relative humidity, wind speed and evapotranspiration (ETo) were collected from an automated weather station belonging to the Central Laboratory for Agricultural Climate (CLAC). The soil temperature at 15 cm depth was measured daily at 12:00 a.m. using a soil thermometer**.**

5)– Water use efficiency (WUE): Water use efficiency of treatment was calculated according to **FAO (1982)** as follows: The ratio of crop yield (Y) to the total amount of irrigation water used for the growth season (IR); WUE (kg/m^3) = Y (kg) / IR (m^3).

6)- Economic study: The economic evaluation was estimated by calculating the cost of cultivation for different agro-inputs, *i.e.*, labors, irrigation, fertilizers, harvesting, and other necessary experimental requirements. Pumping water costs were divided into two main categories: (i) fixed cost and (ii) operating costs, which vary directly with the number of operating hours. The average cost of pumping one cubic meter of water was estimated by 0.12 L.E. (Egyptian pound) according to **Abdrabbo *et al.* (2021).**The returns of each tested treatment were calculated according to **Cimmyt (1988).**

7) Statistical analysis: Analysis of data was done, using SAS program for statistical analysis. The differences among means for all traits were tested at 5 % level of probability according to **Waller and Duncan (1969)**.

Table 2: The average weekly irrigation requirements (m^3 $feddan^{-1}$) under different studied irrigation levels for onion cultivated in Dokki site during 2019/2020 and 2020 /2021 seosons.

Date	1st season			Date	2nd season		
	100%	75%	50%		100%	75%	50%
29/11/2010	7.2	5.41	3.61	22/11/2011	7.3	5.47	3.65
06/12/2010	8.4	6.31	4.21	29/11/2011	8.5	6.38	4.25
13/12/2010	10.2	7.64	5.10	06/12/2011	10.3	7.74	5.15
20/12/2010	11.6	8.71	5.81	13/12/2011	11.8	8.81	5.9
27/12/2010	14.3	10.69	7.13	20/12/2011	14.4	10.82	7.2
03/01/2011	17.3	12.97	8.65	27/12/2011	17.5	13.13	8.75
10/01/2011	20.1	15.05	10.04	03/01/2012	20.3	15.23	10.15
17/01/2011	22.9	17.19	11.46	10/01/2012	23.2	17.40	11.6
24/01/2011	23.4	17.55	11.70	17/01/2012	23.7	17.76	11.85
31/01/2011	26.7	20.03	13.35	24/01/2012	27.0	20.27	13.5
07/02/2011	26.9	20.16	13.44	31/01/2012	27.2	20.41	13.6
14/02/2011	29.4	22.09	14.72	07/02/2012	29.8	22.35	14.9
21/02/2011	28.5	21.41	14.27	14/02/2012	28.9	21.67	14.45
28/02/2011	27.5	20.64	13.76	21/02/2012	27.9	20.89	13.95
06/03/2011	27.1	20.36	13.57	28/02/2012	27.5	20.60	13.75
12/03/2011	25.2	18.92	12.62	06/03/2012	25.5	19.15	12.75
18/03/2011	25.8	19.35	12.90	13/03/2012	26.1	19.58	13.05
24/03/2011	25.9	19.42	12.95	20/03/2012	26.2	19.65	13.1
30/03/2011	25.8	19.33	12.89	27/03/2012	26.1	19.56	13.05
05/04/2011	23.1	17.33	11.56	03/04/2012	23.4	17.54	11.7
11/04/2011	18.9	14.18	9.45	10/04/2012	19.1	14.36	9.55
Total m^3/ feddan /season	3124	2343	1562	Total m^3/ feddan /season	3162	2371	1581

RESULTS AND DISCUSSIONS

Climate data during experiment period:

Table (3) represents the measured climatic data in the open field during the experiment period, from the first week of November till the second week of March (end of the season) for Dokki experimental farm during the 2019/2020 and 2020 /2021 seasons. The recorded maximum and minimum air temperature gradually decreased during November, December, and January and then start to increase gradually from February till the end of the season. The average daily air relative humidity (RH) was decreased gradually after the first month of the experiment (November) till the mid of February during the cultivation period and then RH % start to increase again. There was no clear trend for the wind speed as it was almost the same during both seasons with values around from 1.4 to 2.0 m/s.

Table (3): Average weekly climatic data for Dokki farm during the two seasons 2019/2020 and 2020 /2021.

		1st season				2nd season			
	Week	Max. Temp.	Min. Temp.	RH	Wind Speed	Max. Temp.	Min. Temp.	RH	Wind Speed
		°C	°C	%	m/s	°C	°C	%	m/s
Nov.	1	16.9	10.7	61.7	1.8	18.3	11.1	65.6	1.7
	2	16.3	10.3	62.8	1.9	16.4	10.6	61.6	1.9
Dec.	3	14.9	9.4	57.8	1.9	14.8	10.1	56.0	1.8
	4	15.3	8.3	56.9	1.7	14.8	9.1	55.2	1.8
	5	16.3	8.9	56.9	1.7	17.2	9.3	60.4	1.8
	6	16.6	9.2	55.6	1.8	18.3	9.3	58.6	1.9
Jan.	7	15.8	10.0	53.5	1.8	16.8	10.6	56.7	1.9
	8	16.6	9.0	52.8	1.8	17.6	9.5	56.0	1.9
	9	17.0	8.5	53.5	1.6	18.0	9.0	56.7	1.7
	10	17.1	10.6	52.7	1.8	18.1	11.3	55.9	1.9
Feb.	11	17.5	10.5	54.5	1.7	19.3	10.2	57.8	1.8
	12	19.1	10.7	52.0	1.7	20.3	11.1	55.2	1.8
	13	19.6	11.5	54.7	1.7	19.9	12.2	62.5	1.7
	14	20.0	12.4	56.0	1.6	19.5	13.2	63.5	1.7
March	15	20.5	12.8	53.6	1.6	19.9	13.7	61.5	1.7
	16	21.0	13.1	56.3	1.5	20.4	14.2	59.4	1.6
	17	23.3	15.2	54.6	1.4	22.1	14.4	51.87	1.5
	18	26.4	15.8	53.9	1.5	27.1	16.3	55.51	1.5
	19	29.8	16.7	54.6	1.6	28.3	15.8	51.8	1.5
April	20	30.7	17.4	55.4	1.4	29.6	16.8	53.6	1.4

Average soil temperature at 15 cm depth during the experimental two seasons (Figs. 2 and 3) was affected by the mulching type. Results indicated that the type of polyethylene mulch improved the soil temperature followed by rice straw mulch; the lowest soil temperature during a season was recorded under control (bare soil).

According to **Moreno *et al.*, (2009),** the soil temperature under the different mulches is affected by the type of material employed and the temperatures registered in bare soil are always lower than under mulch treatments. Applying the PE mulch increased clay soil temperature by 1.05, 1.85, and 2.15 C° as compared to PE mulch, rice straw mulch, and bare soil, respectively (Fig. 2). These findings are in agreement with many previous studies. **Moursy *et al.*, (2015)** stated that increment of soil temperature due to the greater solar radiation transmittance of white PE mulch compared with the transparent mulches.

Furthermore, results indicated that soil temperatures under rice straw mulch were lower compared to the PE mulch treatments and higher when compared with the bare soil (Fig. 2). Whereas during the winter season, rice straw mulch segregates the soil from the colder air temperatures and reduces the heat loss from the soil **(Zakher, and Abdrabbo. 2014).** However, higher soil temperatures can quicken plant growth, especially at an earlier growth stage which led to increased production, especially with tubers yield **(Farrag *et al*., 2016)**.

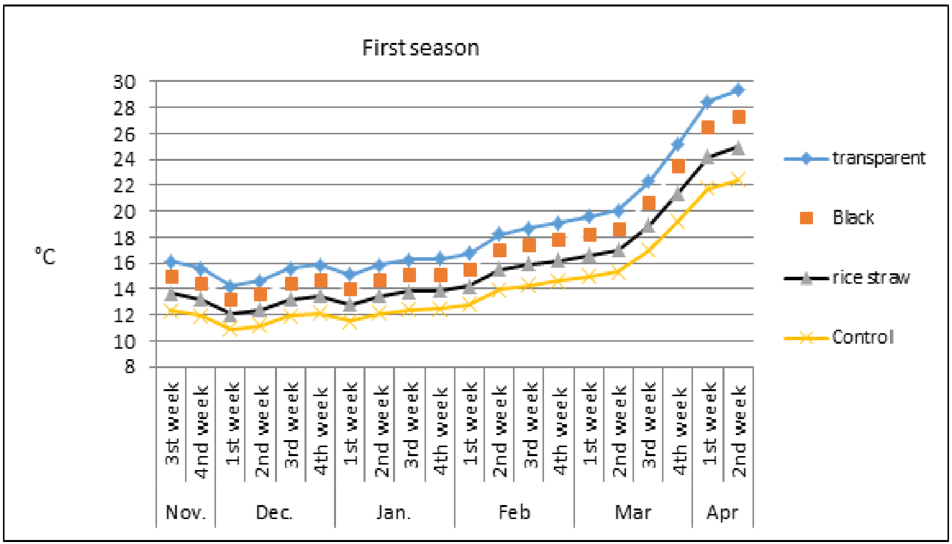

Fig (2): Soil temperature under different soil cover mulch during the first season.

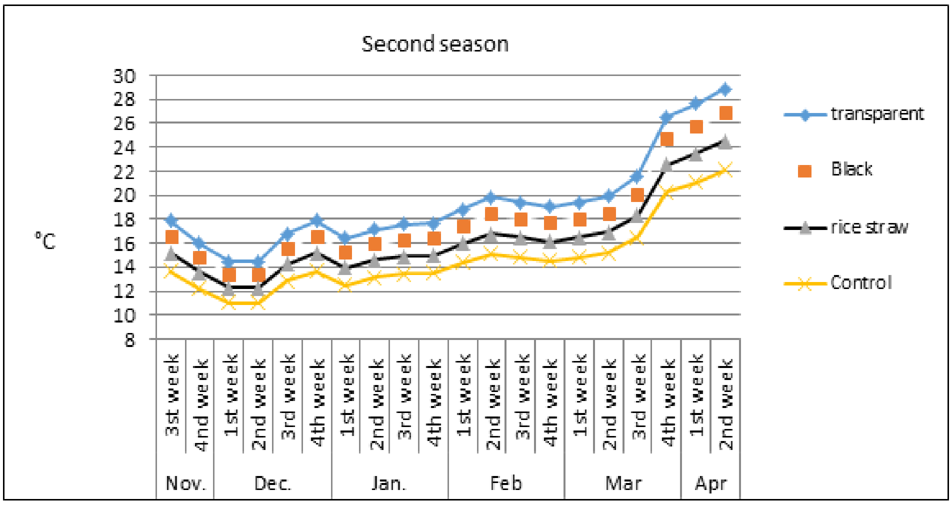

Fig (3): Soil temperature under different soil cover mulch during the second season.

Vegetative characteristics

The obtained results in Table 4 revealed that the application of irrigation rates (IR) significantly affected different vegetative characteristics (Plant length, number of leaves per plant, and fresh and dry weight of leaves) in the two growing seasons. Data indicated that 100 % IR from the recommended level gave the highest plant length, number of leaves per plant, fresh weight of onion leaves followed by 75 % IR during the two tested seasons. The lowest celery vegetative characteristics were obtained by 50% IR.

Table (4): Effect of irrigation level and soil cover treatments on vegetative characteristics (plant length, number of leaves per plant, and fresh & dry weight of leaves)at 90 days after planting during 2019/2020 and 2020/2021 seasons.

	2019/2020					2020/2021				
Plant height (cm)										
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	77.0 b	89.7 a	92.7 a	89.3 a	87.2 A	77.4 b	94.7 a	94.6 a	95.3 a	90.5 A
75%	89.0 a	90.0 a	92.3 a	85.0 ab	89.1 A	91.4 a	96.0 a	94.1 a	92.3 a	93.4 A
100%	85.3 ab	93.0 a	88.7 a	89.7 a	89.2 A	92.3 a	97.5 a	95.3 a	94.3 a	94.9 A
Mean	83.8 B	90.9 A	91.2 A	88.0 AB		87.0 B	96.1 A	94.7 A	94.0 A	
No. of leaves/plant										
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	8.7 c	10.0 abc	9.3 bc	9.3 bc	9.3 B	10.0 e	11.0 cde	10.7 de	10.3 de	10.5 B
75%	9.7 abc	11.0 a	11.0 a	10.7 ab	10.6 A	11.3 bcd	12.3 ab	12.3 ab	12.0 abc	12.0 A
100%	10.7 ab	11.0 a	11.0 a	11.0	10.9 A	12.0 abc	12.7 a	12.0 abc	12.0 abc	12.2 A
Mean	9.7 B	10.7 A	10.4 A	10.3 AB		11.1 B	12.0 A	11.7 AB	11.4 AB	
Leaves fresh wt. (g)										
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	103.7 f	151.0 cd	145.0 de	144.0 e	135.9 C	113.7 f	148.0 de	146.1 de	142.4 e	137.5 C
75%	147.0 de	177.7 b	157.7 c	146.3 de	157.2 B	156.2 d	192.3 b	169.7 c	170.3 c	172.1 B
100%	181.3 b	218.7 a	215.0 a	183.3 b	199.6 A	175.4 c	211.0 a	209.7 a	194.7 b	197.7 A
Mean	144.0 D	182.4 A	172.6 B	157.9 C		148.5 D	183.8 A	175.1 B	169.1 C	
Leaves Dry wt. (g)										
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	13.4 d	17.5 c	17.1 c	17.1 c	16.3 C	15.7 f	19.2 de	19.3 de	18.8 e	18.3 C
75%	17.7 c	19.9 b	18.4 c	17.5 c	18.4 B	21.0 cd	23.6 b	21.2 cd	22.5 bc	22.1 B
100%	20.4 b	24.0 a	23.8 a	21.0 b	22.3A	22.5 bc	25.9 a	25.8 a	24.3 ab	24.6 A
Mean	17.1 D	20.5 A	19.8 B	18.5 C		19.8 C	22.9 A	22.1 AB	21.9 B	

Regarding cover soil treatments for onion plants, black and transparent PE mulch gave the highest onion plant growth during the two seasons followed by rice straw soil mulch. Control treatment gave the lowest plant length, number of leaves per plant and fresh weight of leaves during the two seasons.

The interaction between irrigation rates and mulch treatments was significant for vegetative characteristics during the two studied seasons. The highest vegetative growth was preceded by 100% IR combined by black or white PE mulch followed by 75% IR combined rice straw mulch. The lowest vegetative characteristics were obtained by 50% IR combined with control (bare soil). The same results were obtained by **El-Noemani *et al*., (2009)** who concluded that shortening of plant height under less soil moisture stress may be associated due to the closure of stomata to conserve soil moisture evaporation, this leads to reduce uptake of CO_2 and nutrient. Therefore, photosynthesis and other biochemical reactions are hindered, eventually affecting plant growth. **Kumar *et al*., (2007)** confirmed that high soil moisture application improved vegetation growth via increased plant metabolic activities, which eventually leads to marketable bulb yield increment. Furthermore, **Farrag *et al.*, (2016)**indicated that using polyethylene mulch or rice straw mulch enhanced plant growth parameters under the same water supply. **Abdrabbo *et al*, (2009)** concluded that using mulch during the winter season enhances plant growth and productivity under the same irrigation rate. **David *et al*., (2016**) showed that, when the crop is subjected to water stress at development and late growth stages at varying levels, soil moisture is depleted through absorption by the roots leading to reduced physiological activities which in turn affect root developments.

Onion component and yield

Regarding average neck diameter, bulb diameter, and bulb length of onion, the highest neck diameter, average width, and length of onion bulbs were obtained by 100% IR followed by 75% and 50% IR during the two studied seasons.

The effect of soil cover on average neck diameter, bulb diameter, and bulb length of onion (Table 5) the highest average neck diameter, bulb diameter, and bulb length of onion values were obtained by black polyethylene mulch followed by white polyethylene mulch; the lowest polyethylene mulch was obtained by control treatment.

Table (5):Effect of irrigation level and soil cover treatments on yield component and yield (average neck diameter, bulb diameter, and bulb length) of onion during 2.19/2020 and 2020/2021 seasons.

	2019/2020					2020/2021				
Neck diameter (cm)										
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	1.9 c	2.3 b	2.3 b	2.3 b	2.2 B	1.8 d	2.3 abc	2.3 abc	2.3 abc	2.2 B
75%	1.9 c	2.4 ab	2.4 ab	2.3 b	2.3 B	2.1 cd	2.5 ab	2.4 ab	2.3 abc	2.3 AB
100%	2.4 b	2.7 a	2.7 a	2.5 ab	2.6 A	2.2 bc	2.5 a	2.5 ab	2.5 ab	2.4 A
Mean	2.1 B	2.5 A	2.5 A	2.3 A		2.0 B	2.5 A	2.4 A	2.4 A	
Bulb diameter (cm)										
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	6.9 f	7.3 bcde	7.1 cdef	7.0 def	7.1 B	6.7 e	7.6 abcd	7.3 bcde	7.1 de	7.2 B
75%	7.0 ef	7.7 ab	7.3 cde	7.1 def	7.2 B	7.0 de	7.9 abc	7.5 abcd	7.2 cde	7.4 B
100%	7.3 cde	7.7 a	7.5 abc	7.4 abcd	7.5 A	7.5 abcd	8.1 a	8.0 ab	7.8 abc	7.8 A
Mean	7.0 C	7.6 A	7.3 B	7.2 BC		7.1 C	7.9 A	7.6 AB	7.4 BC	
Bulb length (cm)										
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	5.4 d	6.5 ab	6.3 ab	5.6 cd	5.9 B	4.5 e	5.9 bc	5.8 bc	4.9 d	5.3 C
75%	5.6 cd	6.5 ab	6.4 ab	6.1 bc	6.1 AB	5.5 c	7.0 a	6.8 a	5.8 bc	6.3 B
100%	6.2 bc	6.9 a	6.8 a	6.5 ab	6.6 A	5.9 bc	7.3 a	7.1 a	6.2 b	6.6 A
Mean	5.7 C	6.6 A	6.5 A	6.1 B		5.3 C	6.7 A	6.6 A	5.6 B	

The presented data in Table 6 show there was a significant difference between irrigation treatments during both seasons. The highest average bulb weight, marketable and total yield (ton per feddan) was obtained by 100 % IR followed by 75% IR during both studied seasons. The lowest average bulb weight, the marketable, and the total yield of onion were obtained by 50 % IR. Regarding the soil cover treatments data in Table 6 show the onionaverage bulb weight, marketable and total yield during the two tested seasons. There were significant differences between the tested treatments. Using black polyethylene gave the highest average bulb weight, marketable and total yield followed by white polyethylene straw while the lowest average bulb weight, marketable and total yield were obtained by control treatment.

Regarding the interaction effect between IR rates and spray garrison, the highest average bulb weight, and total yield was obtained by 100% IR combined by black polyethylene mulch during the two tested seasons; 100% IR combined with transparent polyethylene came in the second order. The lowest average bulb weight, marketable and total yield was obtained 50% IR combined by control (Table 6).

Water stress results in a reduced yield of marketable bulbs due to the earlier ripening of bulbs. Appropriate water supply during the development and ripening stages increases bulb yield. Monitoring soil moisture is therefore important to determine when irrigation may be needed **(Khokhar, 2018).** However, water deficit during the crop cycle leads to a significant reduction of bulb size, which suggests the need to finely adjust water management in this crop **(Rattin *et al.,* 2011).** The relation between irrigation rate and onion yield was studied by **Bhagyawant *et al.,* (2016)**who reported that there is a linear relationship between the decrease in relative water consumption and the decrease in relative yield. **Olalla *et al*., (2004)** reported that plots that received the greatest volumes of water during the development and ripening stages yielded harvests with higher percentages of large-size bulbs whereas the water shortages induced during the vegetation growth and bulb formation stages led to higher percentages of small-size bulbs.

Table (6): Effect of irrigation level and soil cover treatments on yield component and yield (bulb weight, yield, and marketable yield) for onion during 2019/2020 and 2020/2021 seasons.

	2019/2020					2020/2021				
Bulb weight/ g										
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	133.0 f	171.7 bc	157.7 de	148.0 e	152.6 C	123.9 i	171.6 bcd	155.6 fg	142.0 gh	148.3 C
75%	151.0 e	177.7 b	173.0 bc	164.0 cd	166.4 B	139.6 h	169.4 cde	164.9 def	163.6 def	159.4 B
100%	163.3 cd	217.3 a	182.3 b	181.7 b	186.2 A	158.3 ef	206.4 a	180.3 bc	182.7 b	181.9 A
Mean	149.1 C	188.9 A	171.0 B	164.6 B		140.6 C	182.5 A	166.9 B	162.8 B	
Yield(ton/ feddan)										
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	10.6 f	13.7 bc	12.6 de	11.8 e	12.2 C	9.9 i	13.7 bcd	12.4 fg	11.4 gh	11.9 C
75%	12.1 e	14.2 b	13.8 bc	13.1 cd	13.3 B	11.2 h	13.6 cde	13.2 def	13.1 def	12.8 B
100%	13.1 cd	17.4 a	14.6 b	14.5 b	14.9 A	12.7 ef	16.5 a	14.4 bc	14.6 b	14.6 A
Mean	11.9 C	15.1 A	13.7 B	13.2 B		11.2 C	14.6 A	13.4 B	13.0 B	
Marketable Yield (ton/ feddan)										
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	8.51 h	11.67 def	10.72 efg	9.83 gh	10.18 C	8.13 f	11.67 cd	10.46 de	9.54 ef	9.95 C
75%	10.27 fg	12.51 bcd	12.04 cde	11.41 def	11.56 B	9.60 ef	12.06 bcd	11.48 d	11.39 d	11.13 B
100%	11.76 def	16.69 a	13.86 b	13.52 bc	13.96 A	11.40 d	15.52 a	13.27 bc	13.45 b	13.4 1 A
Mean	10.18 C	13.62 A	12.21 B	11.59 B		9.71 C	13.08 A	11.74 B	11.46 B	

Abbey and Joyce (2004) reported that deficit irrigation especially on the sandy loam caused physiological stress that reduced spring onion growth and dry-matter yield compared to regular irrigation. Regarding neck diameter, **Metwally (2011)** reported that a higher level of applied water resulted in a significantly thicker neck. In general, the result shows decreasing irrigation water application level caused a significant effect on onion neck diameter. **Leskovar (2010)**reported that it would be possible to adjust water conservation practices to a 75 percent crop evapotranspiration rate, as a means to target high-price bulb sizes without reducing quality. These results emphasize that adequate soil moisture content along the growing period encouraged the vegetative growth of the plant and enhanced the development of large and medium bulb size which is considered to be marketable.

Water use efficiency (WUE):-

Table (7) presents the WUE efficiency for different irrigation levels and soil cover, the highest water efficiency was obtained by 50% IR followed by 75% IR; the lowest WUE was obtained by 100% IR during the two studied seasons. As for soil cover, the black polyethylene mulch gave the highest WUE followed by transparent polyethylene mulch and rice straw mulch. The lowest WUE was obtained by bare soil treatment during both tested seasons. The interaction effect between irrigation and mulch treatments indicated that 50% IR combined with black mulch gave the highest WUE; while 100% IR combined with control gave the lowest WUE during both seasons. This result is in line with the result of **Samson and Ketema (2007)** how reported that deficit irrigation increased the water use efficiency of onion. According to, a review of reduced water supplies effect on crop yield by **FAO (2002)** deficit irrigation maximizes CWUE in a way that crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season and any yield reduction will be insignificant compared with the benefits gained from the saved water to irrigate other crops. Hence, reducing non-productive loss of irrigation water is best achieved through the integrated use of regulated deficit irrigation along with mulching material for maximum water use efficiency (WUE) in arid and semi-arid lands **(Igbadun *et al.*, 2012).**

Table (7):Effect of irrigation level and soil cover treatments on water use efficiency (kg/ m^3) for onion during 2019/2020 and 2020/2021 seasons.

	2019/2020					2020/2021				
	Water use efficiency									
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	6.81 c	8.79 a	8.08 b	7.58 b	7.81 A	6.27 cd	8.68 a	7.87 ab	7.19 bc	7.50 A
75%	5.16 ef	6.07 d	5.91 d	5.60 de	5.68 B	4.71 fghi	5.72 de	5.56 def	5.52 defg	5.38 B
100%	4.18 g	5.57 de	4.67 fg	4.65 fg	4.77 C	4.00 i	5.22 efgh	4.56 hi	4.62 ghi	4.60 C
Mean	5.38 C	6.81 A	6.22 B	5.94 B		4.99 C	6.54 A	6.00 B	5.78 B	

NPK percentages:-

The obtained data in Table (8) showed that there was a significant difference between the NPK percentages under irrigation levels. The highest NPK content resulted from 100% IR followed by 75 % IR during both seasons, the lowest NPK percentages were obtained by 50 % IR. On the other hand, black mulch led to increasing the NPK percentage in onion leaves followed by transparent mulch, while the control gave the lowest NPK percentages (Table 8). Regarding the interaction effect, 100% IR combined with black mulch gave the highest NPK percentages followed by 100% IR combined with transparent mulch; while the lowest NPK percentages were obtained by 50% IR combined with control during both seasons.Regarding TSS in the onion bulbs data indicated that the highest TSS values were obtained by 50 % IR followed by 75% IR during both seasons. Control treatment gave the highest TSS compared with different mulch treatments during both seasons. The polyethylene mulch treatments gave the lowest TSS values. The same results were confirmed by **Abdrabbo *et al*., (2009) and Nguye *et al*., (2012)** who confirmed the obtained data by stating that adequate irrigation quantity increased the nutritional content. Furthermore, **Liasu and Achakzai (2007)** discovered that wild sunflower leaf mulch, both alone and with fertilizer (NPK), improves tomato plant growth and development in terms of leaf number, height, and fruit yield. Plastic mulching increased crop growth rate due to effective weed control and improved nutrient usage as a result of both scant rainfall and insufficient irrigation water (**Lamont, 1996**). Organic mulches have been shown to increase crop growth and yield by increasing soil water content, increasing heat energy, and adding some organic nitrogen and other minerals to improve soil nutrient status. Mulching has been shown to alter organic matter content, microbial activity, soil nutrient availability, erosion management, and soil compaction (**Stowell, 2000**). Mulch enhances soil nutrient and water retention encourages beneficial soil microbial activity and worms but inhibits weed growth. Mulching, when done correctly, can dramatically increase plant health and reduce upkeep when compared to bare soil culture (**Ramakrishna *et al*., 2006**). Plastic mulches provide several advantages, including increased yields and improved fruit quality. These benefits of mulching in vegetable production have been related to increases in soil temperature, regulation of soil moisture and nutrients through reduced soil evaporation, and nutrient leaching (**Steinmetz *et al*., 2016**). Regarding TSS, **Hafez and Gomaa (2018)** reported that bare soil treatment gave the highest TSS content when compared with black plastic or straw of date palm leaves treatments. On the other hand, it was found that TSS significantly decreased with increasing water levels compared with low irrigation treatment (Table 9). Similor results were obeained by **Mohamed and Gamie (2000).** Resuls in Table (9) indicated that free proline value, in the onion leaf dry weight, was influenced by irrigation treatments. The highest free proline value was obtained by the lowest irrigation treatment (50% IR) followed by 75% IR. The lowest free proline was obtained by 100% IR during both seasons. Regarding the mulch treatments. The highest proline concentration was obtained by control treatment followed by rice straw mulch, the lowest proline values were obtained by black mulch. As for the interaction effect of irrigation level and mulch treatments, the highest proline was obtained by 50% IR combined by control followed by 50% IR combined by rice straw mulch. The lowest proline value was obtained 100% IR combined by black mulch during the two seasons. The results are in line with those obtained by **Semida *et al*., (2016)** who concluded that deficit irrigation led to increasing free proline concentration in the onion dry leaves. On the other hand, **Farrag *et al*., (2016)** concluded that mulch treatments led to enhance soil moisture compared with control which led to the relief of the negative effects of water deficit.

Table (8):Effect of irrigation level and soil cover treatments on N, P, and K of onion at 90 days after planting during 2019/2020 and 2020/2021 seasons.

	2019/2020					2020/2021				
					N					
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	1.80 f	1.90 ef	2.02 d	2.00 de	1.93 C	1.58 e	1.92 d	1.89 d	1.88 d	1.82 C
75%	2.29 c	2.52 b	2.51 b	2.28 c	2.40 B	2.12 c	2.38 ab	2.39 ab	2.13 c	2.26 B
100%	2.55 b	2.83 a	2.73 a	2.60 b	2.68 A	2.26 bc	2.55 a	2.50 a	2.43 a	2.44 A
Mean	2.21 C	2.42 A	2.42 A	2.29 B		1.99 C	2.28 A	2.26 A	2.15 B	
					P					
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	0.17 e	0.25 ab	0.24 abc	0.20 cde	0.22 C	0.18 d	0.27 ab	0.25 abc	0.20 cd	0.23 B
75%	0.19 de	0.27 ab	0.27 ab	0.25 abc	0.25 B	0.18 d	0.27 ab	0.27 abc	0.26 abc	0.24 AB
100%	0.23 bcd	0.29 a	0.28 ab	0.27 ab	0.27 A	0.23 bcd	0.30 a	0.27 ab	0.26 abc	0.27 A
Mean	0.20 C	0.27 A	0.26 A	0.24 B		0.20 C	0.28 A	0.26 A	0.24 B	
					K					
Irrigation level (%)	Mulch									
	Control	Black	White	Straw	Mean	Control	Black	White	Straw	Mean
50%	1.29 f	1.55 e	1.55 e	1.53 e	1.48 C	1.35 e	1.56 cd	1.58 cd	1.56 cd	1.51 C
75%	1.50 e	1.89 bc	1.83 c	1.73 d	1.74 B	1.46 de	2.00 ab	1.95 b	1.76 c	1.79 B
100%	1.71 d	2.12 a	2.06 a	1.92 b	1.95 A	1.68 c	2.17 a	2.18 a	2.00 ab	2.01 A
Mean	1.50 D	1.85 A	1.82 B	1.73 C		1.50 C	1.91 A	1.90 A	1.77 B	

Table (9):Effect of irrigation level and soil cover treatments on TSS and free proline of onion during 2019/2020 and 2020/2021 seasons.

Irrigation level (%)	2019/2020					2020/2021				
	TSS									
	Mulch									
	Control	**Black**	**White**	**Straw**	**Mean**	**Control**	**Black**	**White**	**Straw**	**Mean**
50%	**15.8 a**	**14.5 c**	**14.4 c**	**15.7 a**	**15.1 A**	**15.6 a**	**14.4 bc**	**14.7 b**	**14.4 bc**	**14.8 A**
75%	**14.9 b**	**13.5 d**	**13.6 d**	**14.2 c**	**14.0 B**	**14.7 b**	**13.2 de**	**13.4 de**	**13.7 cd**	**13.7 B**
100%	**13.3 de**	**11.9 g**	**12.4 f**	**13.1 e**	**12.7 C**	**13.0 de**	**12.1 f**	**12.1 f**	**12.8 ef**	**12.5 C**
Mean	**14.6 A**	**13.3 C**	**13.5C**	**14.3 B**		**14.4 A**	**13.2 B**	**13.4 B**	**13.6 B**	
	Free proline mg per g of leaf dry weight									
	Mulch									
Irrigation level (%)	**Control**	**Black**	**White**	**Straw**	**Mean**	**Control**	**Black**	**White**	**Straw**	**Mean**
50%	**1.16 a**	**0.96 c**	**1.01 c**	**1.10 b**	**1.06A**	**1.09 a**	**0.92 b**	**0.96 b**	**0.97 b**	**0.99 A**
75%	**0.85 d**	**0.68 gh**	**0.77 ef**	**0.80 de**	**0.78 B**	**0.81 c**	**0.67 efg**	**0.73 de**	**0.77 cd**	**0.75 B**
100%	**0.77 ef**	**0.64 h**	**0.69 gh**	**0.73 fg**	**0.71 C**	**0.74 cde**	**0.63 g**	**0.65 fg**	**0.71 def**	**0.68 C**
Mean	**0.93 A**	**0.76 D**	**0.82 C**	**0.88 B**		**0.88 A**	**0.74 D**	**0.78 C**	**0.82 B**	

Economic analysis:-

The operating costs of producing one feddan of onion using various irrigation and soil cover treatments were calculated, including seasonal costs such as labor, irrigation, fertilization, and so on (Tables 10 and 11). The irrigation cost was estimated as described by **(Abdrabbo *et al.*, 2021),** who take into account the irrigation cost as well as the operation and maintenance costs. The weight of the marketable yield was used to estimate onion production. During both years, the price of the local market was collected based on the wholesale market. During both seasons, 100 % IR combined with black mulch produced the highest net income per feddan. The second season resulted in a higher net income due to an increase in the wholesale price of onions. Even though the manual was less expensive than the mulch, the net profit from the mulch treatments was higher than the control due to higher productivity per feddan. Due to higher production, which covered the operation and maintenance of the irrigation system, the highest irrigation level (100 % IR) provided the highest net profit compared to the other irrigation treatments. Because transparent mulch is more expensive, the black mulch yielded a higher net profit than the transparent mulch.

Table (10):Effect of irrigation level and soil cover treatments on economic analysis for onion during 2019/2020 seasons.

Irrigation	Mulch	Irrigation cost / LE per feddan	Mulch cost / LE per feddan	Manual weeding cost / LE per feddan	Others cost (irrigation, fertilizer…) / LE per feddan	Total production costs / LE per feddan	Average price/ LE per Ton	Total yield / Ton per feddan	Total return / LE per feddan	Net profit / LE per feddan
50%	control	546.7	0	1920	10800	13267	1500	10.6	15900	2633
	Black	546.7	3940	0	10800	15287	1500	13.7	20550	5263
	Transparent	546.7	4920	0	10800	16267	1500	12.6	18900	2633
	Rice straw	546.7	4360	0	10800	15707	1500	11.8	17700	1993
75%	control	820.1	0	1920	10800	13540	1500	12.1	18150	4610
	Black	820.1	3940	0	10800	15560	1500	14.2	21300	5740
	Transparent	820.1	4920	0	10800	16540	1500	13.8	20700	4160
	Rice straw	820.1	4360	0	10800	15980	1500	13.1	19650	3670
100%	control	1093.4	0	1920	10800	13813	1500	13.1	19650	5837
	Black	1093.4	3940	0	10800	15833	1500	17.4	26100	10267
	Transparent	1093.4	4920	0	10800	16813	1500	14.6	21900	5087
	Rice straw	1093.4	4360	0	10800	16253	1500	14.5	21750	5497

Table (11): Effect of irrigation level and soil cover treatments on Economic analysis for onion during 2020/2021 seasons.

Irrigation	Mulch	Irrigation cost / LE per feddan	Mulch cost / LE per feddan	Manual weeding cost / LE per feddan	Others cost (irrigation, fertilizer…) / LE per feddan	Total production costs / LE per feddan	Average price/ LE per Ton	Total yield / Ton per feddan	Total return / LE per feddan	Net profit / LE per feddan
50%	control	553.4	0	1920	10800	13273	1650	9.9	16335	3062
	Black	553.4	3940	0	10800	15293	1650	13.7	22605	7312
	Transparent	553.4	4920	0	10800	16273	1650	12.4	20460	4187
	Rice straw	553.4	4360	0	10800	15713	1650	11.4	18810	3097
75%	control	830.0	0	1920	10800	13550	1650	11.2	18480	4930
	Black	830.0	3940	0	10800	15570	1650	13.6	22440	6870
	Transparent	830.0	4920	0	10800	16550	1650	13.2	21780	5230
	Rice straw	830.0	4360	0	10800	15990	1650	13.1	21615	5625
100%	control	1106.7	0	1920	10800	13827	1650	12.7	20955	7128
	Black	1106.7	3940	0	10800	15847	1650	16.5	27225	11378
	Transparent	1106.7	4920	0	10800	16827	1650	14.4	23760	6933
	Rice straw	1106.7	4360	0	10800	16267	1650	14.6	24090	7823

CONCLUSION

This study produced good evidence on the possibility of using proper irrigation quantity and polyethylene or rice straw mulch led to enhance the growth as well as productivity of onion. Irrigation levels and soil cover treatments in the present study showed their effect on onion productivity. The present study revealed that the irrigation level 100 % and black polyethylene is the best conditions for high crop yield and quality. While the best conditions for water use sufficiency were obtained under irrigation level 50 % and black mulch. On the other hand, the economic analysis recommends using 100% irrigation level combined with black polyethylene mulch to obtain the highest net profit.

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تقييم أنواع تغطية سطح الارض و مستويات الري على الإنتاجية و كفاءة استخدام المياه فى البصل

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أجريت التجربة في مزرعة الدقي التابعة للمعمل المركزي للمناخ الزراعي، مركز البحوث الزراعية ، وزارة الزراعة و إستصلاحالأراضى ، محافظة الجيزة ، مصر ، خلال موسمى 2020/2019 و 2021/2020. بهدف دراسة تأثير ثلاثة مستويات للري (50 ، 75 ، 100 % من الاحتياجات الاروائية و التي تستلزم اضافة كميات مياه الري 1571 ، 2357 ، 3143 م^3 للفدان كمتوسط للموسمين) و تم اختبار اربعة معاملات لغطاء التربة (البولي إيثيلين الأسود ، البولي إيثيلين الأبيض. ، قش الارز ، و المقارنة (بدون تغطية) علي نمو و انتاجية محصول البصل على مدى موسمين.

و قد اوضحت النتائج أن جميع معاملات تغطية سطح التربة أدت إلى زيادة درجات حرارة التربة مقارنة بمعاملة بدون غطاء. كما أدى اضافة 100٪ من الاحتياجات الاروائية إلى زيادة معنوية في طول النبات ، وعدد الأوراق لكل نبات ، وأظهر ايضا أن انسب غطاء لسطح التربة لإنتاج البصل كان التغطية بالبولي إيثيلين ، وخاصة اللون الأسود ،. كما أثر غطاء التربة على محتويات نباتات البصل من N و P و .K و كانت افضل

النتائج مع 100٪ من الاحتياجات الاروائيةمع تغططية سطح الترب بالبولي إيثيلين الأسود و كذلك أعلى قيم صافي الدخل. و يمكن ان نستخلص من النتائج المتحصل عليها ان مستوى الري 100٪ (3143 م^3 ماء / فدان كمتوسط موسمين) مع تغطية سطح التربة بالبولي إيثيلين الأسود هو الأفضل لإنتاج محصول وجودة من محصول البصل. في حين تم الحصول على أفضل كفاءة لاستخدام المياه تحت مستوى الري 50٪ مع البولي إيثيلين الأسود.