Maximizing irrigation water use and crop productivity under mulching with geotextile for lettuce plants (*Lactuca sativa* L. var. *capitata*)

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Abstract. One of the fields that will be negatively impacted by climate change is agriculture, particularly in developing countries. Most crops are affected when grown under limited water supplies as it produces low productivity, especially during the late growing stage. For this reason, it is important to improve irrigation efficiency and crop yield. Two successive seasons were conducted during 2021 and 2022 to test the action of mulching types on iceberg lettuce plants (*Lactuca sativa* L. var. *capitata*) with irrigation stress. In the sandy loam soil conditions of the El Sharkia Governorate in Belbeis, Egypt, iceberg lettuce plants were grown with different types of mulching (no mulching, white geotextile sheet, and black plastic sheet) under varying levels of water (100, 80, and 60% of ETc, or evapotranspiration). Results showed that mulching the soil surface with plastic and geotextile produced the highest data of soil moisture content inside the root zoon. In conclusion, compared to the control (no mulching), all mulching types treatments result in a significant increase in yield parameters. In this study, however, mulching with white geotextile sheets and requiring 100% ETc irrigation proved to be the statistically most effective treatment, while 80% ETc combined with white geotextile sheet get values were statistically equal to the results with the control (100% ETc without mulching). It is possible to achieve results similar yield to the control or better, while saving an amount of irrigation water of up to 20% by using ETo 80 % combined with mulching with white geotextile sheet without any negative effect on the plant. However, it can be recommended to use geotextile compared to black plastic, as plastic requires more time to degrade, which will be harmful to the environment.

1 Introduction

Capoutshi or iceberg lettuce (*Lactuca sativa* L. var. *capitata*) (Limor) is an important vegetable crop worldwide. It has been increased in recent years, especially in the

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Mediterranean [1]. It has a significant effect on the human diet, with medicinal and functional properties [2]. 3196 hectares of land were planted to produce 70839 tonnes of lettuce, with an average yield of 22.16 tons per hectare. Meanwhile, 385 hectares were planted to produce 7443 tonnes of lettuce, with an average yield of 19.33 tonnes per hectare, according to [3]. In a semi-arid ecosystem, the most important factor limiting crops production is water stress. This has been observed in studies conducted by [4, 5]. Therefore, mulching can be an effective technique to reduce soil evaporation, but its efficiency depends on meteorological conditions and the characteristics of the different mulching materials [6]. In addition to maintaining soil moisture, also, mulches have many other advantageous effects such as limiting excessive temperature variations in the soil, reducing evaporation of water, maintaining soil fertility, promoting growth and production, and increasing the quantity of stored soil moisture [7, 8]. In order to improve agricultural crops' water use efficiency, soil evaporation must be reduced. One effective strategy to reduce the amount of water vapour that is exchanged between the soil's surface and the atmosphere is to use mulching materials. Thus, compared to bare soil, less water evaporates from mulched soil, leaving more water available for beneficial crop transpiration [10]. The design of a monolithic alternative cover, also known as a phytocap or evapotranspiration (ET) cover, is typically based on the water balance principle, which states that water can be removed by evapotranspiration during active vegetation growing periods and stored in the cover soil during wet periods to minimize percolation [11].

Thus, the main objective of the current investigation was to improve the growth and yield characteristics of lettuce plants in sandy loam soil. Also reduces evaporation from the soil surface to enhance soil moisture in the root zone. To achieve this goal different mulching types were used (without mulching, white geotextile sheet and black plastic sheet) with different irrigation treatments (100, 80 and 60% of ETc “evapotranspiration”).

2 Materials and Methods

Two successive seasons were conducted in 2021 and 2022 to test the effects of mulching types and irrigation levels on iceberg lettuce (*Lactuca sativa* L. var. *capitata*) in sandy loam soil conditions. Thus, the purpose of this investigation was to improve crop characteristics and yield of Iceberg lettuce plants with the application of several mulching techniques (without mulching, white geotextile sheet and black plastic sheet) with various amounts of irrigation (100, 80 and 60% of ETc i.e. evapotranspiration) under drip irrigation system at Belbeis region – El Sharkia Governorate, Egypt.

2.1 Calculate water requirements

After transplanting, amounts of irrigation (100, 80 and 60% of ETc) were added. Irrigation scheduling was calculated using the Eq. (1):

$$IR_g = \frac{(ET_o \times k_c \times K_r)}{E_i} - P + LR \quad (1)$$

Where: IRg is irrigation requirements, mm day^{-1}, ET_O is reference evapotranspiration, mm day^{-1}, Kc is crop coefficient [12], Kr is ground cover reduction factor, Ei = is irrigation efficiency, %, R is precipitation, mm (for example rainfall), LR is leaching requirements, mm. The gross amount of irrigation needed each day was calculated from mm/ha/day to m^3 ha^{-1} day^{-1} [13].

In addition, there are three various rates of evapotranspiration (100, 80, and 60% of ETc) with various amounts of water (2626, 2102, and 1575 m^3 ha^{-1}), (2387, 1910, and 1432 m^3 ha^{-1}) for 2021 and 2022 seasons, respectively. water requirements were calculated using

the CROPWAT, 2012 version 8.0.1.1 computer program [14] using meteorological station.

2.2 Trial design

Nine treatments with five replicates were included in the split-plot system complete randomized block design of the experiment. The subplot, the main plot (first factor) consisted of three irrigation levels (100, 80, and 60% of ETc) whereas (second factor) included three various types of mulching (black plastic sheet, white geotextile sheet, and without mulching. This type of geotextile fabrics is characterized by its medium air and water permeability due to pores in its pores. Pore size can be controlled by the areal density measured by Gram per Square Meter of the produced material and also by the material thickness.

Additionally, 1260 m^2 made up the experimental unit area. Lettuce (*Lactuca sativa* L. var. *capitata*) seedlings that were uniformly sized and in good health were chosen from a commercial nursery and transplanted on September 17 of each year. After that, they were cultivated to each line dripper side, spaced 0.3 m apart. The plants were exposed to three different amounts of water delivery after twenty days of planting: 100%, 80%, and 60% of evapotranspiration (ETc). These treatments represent, in turn, the circumstances attained as extreme water deficiency, moderate water deficiency, and adequate water supply, respectively. The plants in every treatment were irrigated every 3 days. At last, all the lettuce plants of this study received the same horticultural practices except experimental treatments.

2.3 Soil moisture content

Before irrigation, soil moisture was monitored, and the field capacity and wilting point were used as assessment lines for the plants' exposure range to water deficiency. Soil depths were used for the measurements. soil moisture was monitored using Profile Probe equipment [15].

2.4 Crop growth parameters

When the lettuce achieved horticultural maturity on December 1st, around 75 days after transplanting, the lettuce plants were harvested. Samples were randomly taken in both seasons on December 1st in order to record the growth parameters and yield. The data recorded were plant height (cm), head diameter (cm), head circumference (cm), head volume (cm^3), plant fresh weight (g), head fresh weight (g), root fresh weight (g), number of leaves / plant, leaf fresh weight, and crop yield (ton ha^{-1}),

Leaf area (cm^2):

To estimate the leaf area (cm^2) leaves were taken from the middle portion of the plant according to [16].

Water productivity:

Water productivity was estimated using equation (2) according to [17].

$$Water\ productivity\ = \frac{total\ yield\ (kg\ \ ha^{-1})}{water\ requirements\ (m^3\ \ ha^{-1})} \quad (2)$$

Leaf total chlorophyll:

A portable chlorophyll metre (SPAD 502) was used to estimate the total chlorophyll in fresh leaves from each plant according to [18].

Leaf TSS content:

A hand refractometer was used to estimate the total soluble solids (TSS %) in fresh

leaves of plant.

Leaf cell sap osmotic pressure (atm):

According to [19] leaves cell sap concentration and osmotic pressure (atm) were estimated.

Statistical analysis:

The trial design was split plot with a complete randomized block design with five replicates. The data recorded were statistically analyzed using the analysis of variance method as reported by [20]. The differences between means were differentiated by using Duncan's range test [21].

3 Results and Discussion

3.1 Soil moisture content inside root zone of lettuce crop

Figure 1 showed that mulching with plastic and geotextile had a significant impact on the rise in soil moisture content in the root zone (also known as the "SMC"). Applying mulching before irrigation resulted in higher SMC values. The application of plastic and geotextile mulch to the soil surface produced the highest SMC values. Moreover, there is no significant between the results under a white geotextile sheet and a black plastic sheet as mulching for the soil surface. Moreover mulching the soil surface further enhances soil moisture availability, soil organic carbon, reducing evaporation from the soil surface, and soil moisture retention over extended periods [6]. Mulches have numerous positive effects in addition to preserving soil moisture, such as preventing excessive temperature fluctuations, lowering evaporation of water, preserving soil fertility, enhancing growth, and increasing yield—all of which lead to a greater amount of soil moisture being stored [7]. Furthermore, as can be observed in Figure 1, a higher rate of moisture storage inside the root zone under mulching with plastic and geotextile will lead to increased water application efficiency [22, 23]. However, it can be recommended to use geotextile compared to black plastic, as plastic requires more time to degrade, which will be harmful to the environment [24].

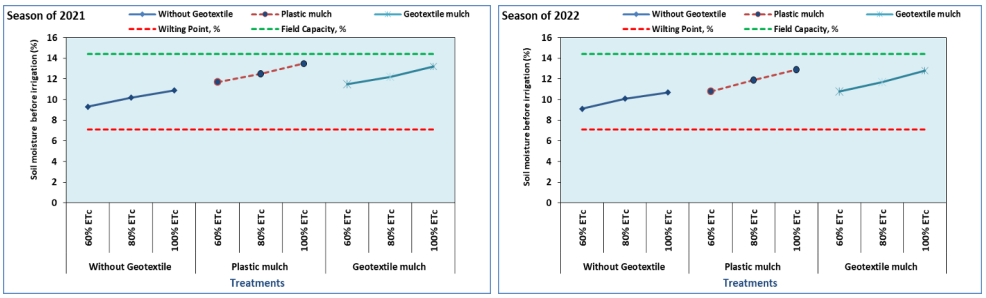

Fig. 1. Effect of without, plastic and geotextile mulch under drip irrigation and irrigation treatments on the rising of moisture within the lettuce root zone during 2021 and 2022 seasons.

3.2 Crop growth parameters

Table 1 shows the benefits of various mulching methods at varying evapotranspiration rates as well as how they interacted with the plant's height, head diameter, head circumference, and head volume parameters during 2021 and 2022 seasons. Under water stress, the plant reached a maximum significant height of 19.19 cm with 100% ETc, whereas in the first season, the plant reached 15.92 cm with 60% ETc. Mulching types: Compared to the

control (no mulching), which recorded 17.21 cm at the first season, mulching with a white geotextile sheet recorded the highest data for a plant height of 18.10 cm. Interaction: Using 100% ETc in conjunction with white geotextile sheet mulching during the first season produced the highest data for plant height, 19.62 cm. Furthermore, in both seasons, the head diameter, head circumference, and head volume all followed the same path towards the plant height.

The results in Table (2) show the effect of different mulching methods at different ETc rates and their interaction on the plant fresh weight, head weight, and roots fresh weight parameters of iceberg lettuce plants in both seasons have a statistically significant effect. For water treatments, 100% ETc obtained optimal data of the plant's fresh weight of 1052.66 g compared to 60% ETc of 521.99 g during the first season. For mulching types, the optimal data for plant fresh weight was obtained under mulching with a white geotextile of 821.84 g compared to the control (no mulching) of 720.86 g for the first season. Interaction: In the first season, the optimal data for plant fresh weight was 1121.49 g, reached by mulching with a white geotextile sheet and 100% ETc. Furthermore, the roots' fresh weight and head weight in both seasons corresponded to the plant's fresh weight.

Table 1. Impact of different types of mulching under water deficiency on plant height, head diameter, head circumference and head volume characteristics of lettuce plants (2021-2022 seasons).

Parameters / Treatments	Plant height (cm)				Head diameter (cm)				Head circumference (cm)				Head volume (cm^3)			
	2021 season		2022 season		2021 season		2022 season		2021 season		2022 season		2021 season		2022 season	
100%ETc	19.19	A	19.22	A	19.92	A	19.76	A	61.40	A	61.21	A	3918.28	A	3882.72	A
80%ETc	17.81	B	17.70	B	18.38	B	18.34	B	56.81	B	56.57	B	3102.37	B	3062.63	B
60%ETc	15.92	C	15.99	C	16.83	C	16.64	C	51.41	C	51.24	C	2303.23	C	2278.49	C
WM	17.21	C	17.12	C	17.87	C	17.88	C	55.09	C	54.94	C	2879.05	C	2851.83	C
MBPS	17.60	B	17.68	B	18.44	B	18.16	B	56.59	B	56.27	B	3105.28	B	3054.40	B
MWGS	18.10	A	18.12	A	18.82	A	18.70	A	57.96	A	57.81	A	3339.54	A	3317.61	A
100%ETcXWM	18.88	b	18.66	c	19.41	c	19.36	c	60.11	c	59.70	c	3672.16	c	3595.92	C
100%ETcXMBPS	19.07	b	19.20	b	19.89	b	19.59	b	61.16	b	60.91	b	3867.19	b	3820.56	B
100%ETcXMWGS	19.62	a	19.81	a	20.47	a	20.33	a	62.94	a	63.02	a	4215.49	a	4231.68	A
80%ETcXWM	17.42	e	17.38	f	18.06	f	18.00	f	55.71	e	55.55	e	2922.77	e	2897.35	E
80%ETcXMBPS	17.84	d	17.70	e	18.36	e	18.28	e	56.84	e	56.49	e	3104.41	e	3047.14	E
80%ETcXMWGS	18.15	c	18.00	d	18.72	d	18.73	d	57.89	d	57.68	d	3279.93	d	3243.39	D
60%ETcXWM	15.34	h	15.31	i	16.15	i	16.28	i	49.44	h	49.59	h	2042.22	h	2062.21	H
60%ETcXMBPS	15.89	g	16.12	h	17.08	h	16.62	h	51.76	g	51.40	g	2344.25	g	2295.51	G
60%ETcXMWGS	16.52	f	16.55	g	17.26	g	17.03	g	53.04	f	52.73	f	2523.21	f	2477.76	F

ETc = evapotranspiration, WM= Without Mulching, MBPS = mulching with black plastic sheet and MWGS = mulching with white geotextile sheet. At the 0.5% level, the means in each column that are followed by the same letter are not substantially different from one another.

Table 2. Impact of different types of mulching under water deficiency on plant fresh weight, head fresh weight, and roots fresh weight characteristics of lettuce plants (2021-2022 seasons).

Parameters	Plant fresh weight (g)				Head fresh weight (g)				Roots fresh weight (g)			
Treatments	2021 season		2022 season		2021 season		2022 season		2021 season		2022 season	
100%ETc	1052.66	A	1077.24	A	1041.37	A	1066.10	A	11.28	C	11.14	C
80%ETc	726.03	B	711.87	B	709.66	B	695.68	B	16.37	B	16.18	B
60%ETc	521.99	C	519.00	C	497.74	C	493.42	C	24.25	A	25.59	A
WM	720.86	C	725.68	C	701.80	C	706.28	C	15.14	C	15.6	C
MBPS	757.98	B	768.15	B	740.28	B	750.24	B	17.7	B	17.91	B
MWGS	821.84	A	814.28	A	806.69	A	798.68	A	19.06	A	19.4	A
100%ETcXWM	997.62	c	1010.54	c	984.87	c	998.34	c	9.98	h	9.92	g
100%ETcXMBPS	1038.86	b	1070.81	b	1027.74	b	1059.51	b	11.12	g	11.29	f
100%ETcXMWGS	1121.49	a	1150.37	a	1111.51	a	1140.45	a	12.75	f	12.2	f
80%ETcXWM	662.99	f	670.60	f	646.02	f	653.21	f	15.71	e	15.07	e
80%ETcXMBPS	720.01	e	716.72	e	703.57	e	700.64	e	16.44	d	16.08	e
80%ETcXMWGS	795.10	d	748.27	d	779.39	d	733.20	d	16.97	d	17.39	d
60%ETcXWM	501.98	h	495.90	i	474.51	h	467.28	i	19.74	c	21.79	c
60%ETcXMBPS	515.07	h	516.93	h	489.54	h	490.57	h	25.53	b	26.35	b
60%ETcXMWGS	548.91	g	544.18	g	529.18	g	522.39	g	27.47	a	28.62	a

ETc = evapotranspiration, WM= Without Mulching, MBPS = mulching with black plastic sheet and MWGS = mulching with white geotextile sheet. At the 0.5% level, the means in each column that are followed by the same letter are not substantially different from one another.

Table (3) demonstrated a statistically significant effect of mulching types under varying water evapotranspiration rates and their interaction on the parameters of leaf area, fresh weight, and number of leaves per plant of iceberg lettuce plants in both seasons. Under water stress, the number of leaves per plant with 100% ETc was 45.37, which was significantly higher than the number of leaves per plant with 60% ETc, which was 30.10 during the first season. When comparing mulching types, the control (without mulching) recorded 36.15 leaves per plant during the first season, while the highest significant value was 38.94 for mulching with white geotextile sheet. The results indicate that in the first season of mulching with white geotextile sheet and 100% ETc, the highest significant value for the number of leaves per plant was 48.06. Furthermore, in both seasons, the parameters of leaf fresh weight and leaf area followed the same pattern as the number of leaves per plant. In general, the crop growth factors improved as the ETo rates raised, This might have resulted from advancements in soil moisture availability, moderate soil surface evaporation, and N, P, and K levels. [25, 26, 27, 28]. The outcomes about water requirements saving aligned with remarks of [29, 30, 31, 32, 33, 34]. Mulches have numerous positive effects in addition to preserving soil moisture, such as preventing excessive temperature fluctuations, lowering evaporation of water, preserving soil fertility, enhancing growth, and increasing yield, all of which lead to a greater amount of soil moisture being stored [7]. This led to increasing yield and improving water use efficiency. Moreover, white geotextile sheet achieved better results than black plastic sheet as mulching for the soil surface because it allowed better gas exchange.

Table 3. Impact of different types of mulching under water deficiency on numbers of leaves per plant, leaf fresh weight, and leaf area characteristics of lettuce plants (2021-2022 seasons).

Parameters	No. of leaves per plant				Leaf fresh weight (g)				Leaf area (cm^2)			
Treatments	2021 season		2022 season		2021 season		2022 season		2021 season		2022 season	
100%ETc	45.37	A	46.57	A	14.55	A	14.30	A	189.88	A	186.63	A
80%ETc	36.99	B	36.59	B	10.36	B	10.47	B	135.22	B	136.60	B
60%ETc	30.10	C	30.25	C	8.18	C	8.29	C	106.71	C	108.25	C

WM	36.15	C	35.91	C	9.77	C	9.94	C	127.47	C	129.70	C
MBPS	37.36	B	37.91	B	11.29	B	11.22	B	147.40	B	146.41	B
MWGS	38.94	A	39.58	A	12.02	A	11.90	A	156.94	A	155.37	A
100%ETcXWM	43.25	c	43.61	c	11.65	c	11.74	c	152.05	c	153.28	c
100%ETcXMBPS	44.79	b	46.44	b	15.38	b	14.77	b	200.77	b	192.73	b
100%ETcXMWGS	48.06	a	49.66	a	16.61	a	16.39	a	216.83	a	213.88	a
80%ETcXWM	35.99	e	35.23	f	10.11	e	10.15	e	131.99	e	132.49	e
80%ETcXMBPS	37.28	d	36.90	e	10.26	e	10.50	d	133.97	e	137.06	d
80%ETcXMWGS	37.68	d	37.64	d	10.70	d	10.75	d	139.69	d	140.27	d
60%ETcXWM	29.20	h	28.90	i	7.54	h	7.92	g	98.37	h	103.35	g
60%ETcXMBPS	30.01	g	30.40	h	8.23	g	8.38	f	107.46	g	109.44	f
60%ETcXMWGS	31.09	f	31.44	g	8.76	f	8.58	f	114.30	f	111.96	f

ETc = evapotranspiration, WM= Without Mulching, MBPS = mulching with black plastic sheet and MWGS = mulching with white geotextile sheet. At the 0.5% level, the means in each column that are followed by the same letter are not substantially different from one another.

Table (4) showed that the different mulching methods under different water evapotranspiration rates and their interaction on the yield and water productivity of lettuce plants in 2021 and 2022 seasons. Under water stress, the optimal data for fresh matter yield was 174.96 tonnes ha^{-1} with 100% ETc compared to 83.61 tonnes ha^{-1} with 60% ETc; similarly, the optimal data for water productivity was 107.99 kg m-3 with 100% ETc compared to 83.74 tonnes ha^{-1} with 60% ETc at the first season. The optimal data for fresh matter yield was 135.52 tonnes per hectare when using white geotextile sheets, when compared to 117.9 tonnes per hectare for control (without mulching), while the optimal data for water productivity was 102.59 kg m^{-3} for mulching with white geotextile sheet. While the control treatment (without mulching) recorded the lowest data (87.00 kg m^3) in the first season. Interaction, the optimal data for yield fresh matter was 186.74 ton ha^{-1} with 100% ETc combined with the mulching with white geotextile sheet, while the optimal data for water productivity was 115.27 kg m^{-3} with 100% ETc combined with the mulching with white geotextile sheet at the first season; this was true in both seasons. It is noteworthy that, the 80% ETc combined with the mulching with white geotextile sheet get value 101.03 kg m^{-3}, which it's statistically equal to 100% ETc without mulching, that get 102.13 kg m^{-3} for water productivity, it was true in the two seasons. Results of the present work revealed that yield were affected significantly by water supply levels, the present optimal data agree with [29, 30, 31, 32, 33, 34]. This result may be due to that using high water irrigation supply possibly due to the increase in soil moisture availability [27, 38, 39]. The yield increase may be the result of water's impact on several metabolism activities in the plant cell. In addition, an increase in soil moisture may have improved photosynthetic processes, the synthesis of carbohydrates, and yield by increasing soil-available N, K, and P and their uptake in the root zone. [40, 41]. Also, the results gained through mulching types are in the same line with those obtained by [7, 8, 25, 26, 35, 37].

The effects of different mulching techniques at different irrigation rates are shown in Table (5), along with how they affect the parameters of total chlorophyll, leaf cell sap TSS, and leaf cell sap osmotic pressure of iceberg lettuce plants in both seasons. The optimal data for total chlorophyll was 47.62 with 100% ETc, compared to 35.36 with 60% ETc during the first season. Comparing all types of mulching, the application of white geotextile sheets resulted in optimal total chlorophyll, measuring 42.74, whereas the control (without mulching) achieved 39.33 during the first seasonInteraction: in the first season the optimal data for total chlorophyll (49.87) with 100% ETc and mulching with a white geotextile. The same trend was observed in the second season. However, in contrast to total chlorophyll in both seasons, leaf cell sap TSS and osmotic pressure metrics follow the opposite path. This is also true for the interactions between mulching types and water treatments. On this, our

findings on water stress are consistent with [28, 29, 30, 31, 32]. Furthermore, the outcomes from various mulching techniques are likened to those obtained by [7, 8, 25, 26, 34, 35, 37].

Table 4. Impact of different types of mulching under water deficiency on yield and water productivity of lettuce plants (2021-2022 seasons).

Parameters	Yield fresh matter (ton ha^{-1})				Water productivity			
Treatments	2021 season		2022 season		2021 season		2022 season	
100%ETc	174.96	A	179.112	A	107.99	A	110.56	A
80%ETc	119.232	B	116.88	B	91.99	B	90.18	B
60%ETc	83.616	C	82.896	C	83.74	C	82.99	C
WM	117.912	C	118.656	C	87.00	C	87.36	C
MBPS	124.368	B	126.048	B	94.13	B	95.16	B
MWGS	135.528	A	134.184	A	102.59	A	101.20	A
100%ETcXWM	165.456	c	167.712	c	102.13	b	103.53	c
100%ETcXMBPS	172.656	b	178.008	b	106.58	b	109.88	b
100%ETcXMWGS	186.744	a	191.592	a	115.27	a	118.27	a
80%ETcXWM	108.528	f	109.728	f	83.74	d	84.68	e
80%ETcXMBPS	118.2	e	117.696	e	91.20	c	90.82	d
80%ETcXMWGS	130.944	d	123.168	d	101.03	b	95.04	d
60%ETcXWM	79.728	h	78.504	i	75.13	e	73.88	f
60%ETcXMBPS	82.248	h	82.416	h	84.61	d	84.79	e
60%ETcXMWGS	88.896	g	87.768	g	91.46	c	90.29	d

ETc = evapotranspiration, WM= Without Mulching, MBPS = mulching with black plastic sheet and MWGS = mulching with white geotextile sheet. At the 0.5% level, the means in each column that are followed by the same letter are not substantially different from one another.

Table 5. Impact of different types of mulching under water deficiency on Total Chlorophyll, Leaf cell sap TSS and Leaf cell sap osmotic pressure of lettuce plants (2021-2022 seasons).

Parameters	Total Chlorophyll SPAD				Leaf cell sap TSS				Leaf cell sap osmotic pressure (atm)			
Treatments	2021 season		2022 season		2021 season		2022 season		2021 season		2022 season	
100%ETc	47.62	A	49.79	A	3.00	C	3.27	C	2.42	C	2.60	C
80%ETc	39.98	B	41.91	B	4.00	B	3.92	B	3.12	B	3.07	B
60%ETc	35.36	C	34.83	C	4.89	A	4.88	A	3.78	A	3.77	A
WM	39.33	C	39.97	C	4.00	A	4.21	A	3.12	A	3.28	A
MBPS	40.88	B	42.21	B	4.00	A	4.09	B	3.12	A	3.19	B
MWGS	42.74	A	44.36	A	3.89	B	3.77	C	3.04	B	2.96	C
100%ETcXWM	45.80	c	47.13	b	3.00	d	3.50	f	2.42	d	2.77	f
100%ETcXMBPS	47.20	b	49.17	b	3.00	d	3.30	g	2.42	d	2.63	g
100%ETcXMWGS	49.87	a	53.07	a	3.00	d	3.00	h	2.42	d	2.42	h
80%ETcXWM	38.57	f	40.17	d	4.00	c	4.00	d	3.12	c	3.12	d
80%ETcXMBPS	40.07	e	42.07	c	4.00	c	3.97	d	3.12	c	3.10	d
80%ETcXMWGS	41.30	d	43.50	c	4.00	c	3.80	e	3.12	c	2.98	e
60%ETcXWM	33.63	i	32.60	f	5.00	a	5.13	a	3.86	a	3.97	a
60%ETcXMBPS	35.37	h	35.40	e	5.00	a	5.00	b	3.86	a	3.86	b
60%ETcXMWGS	37.07	g	36.50	e	4.67	b	4.50	c	3.61	b	3.49	c

ETc = evapotranspiration, WM= Without Mulching, MBPS = mulching with black plastic

sheet and MWGS = mulching with white geotextile sheet. At the 0.5% level, the means in each column that are followed by the same letter are not substantially different from one another.

4 Conclusion

In summarize, all mulching types treatments significantly improve soil moisture content, the effectiveness of water application, and crop yield compared to the control (without mulching). While 80% ETc combined with white geotextile sheet get values were statistically equal to the results with the control (100% ETc without mulching), mulching with white geotextile sheet and irrigation requirement (100% ETc) were statistically the most effective treatment in this study. Thus, it is possible to achieve results similar yield to the control or better, while saving an amount of irrigation water of up to 20% by using ETo 80 % combined with mulching with white geotextile sheet without any negative effect on the plant. However, it can be recommended to use geotextile compared to black plastic, as plastic requires more time to degrade, which will be harmful to the environment.

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