Original scientific paper
DOI: /10.5513/JCEA01/24.1.3499
Journal of Central European Agriculture, 2023, 24(1), p.115-125

The effect of different types of mulch and different cultivation methods on the quantitative and qualitative traits of sunflower (*Helianthus annuus* L.) in Ahvaz climate

Rezvan Kazemi HASANVAND, Amin Lotfi JALAL-ABADI (✉), Alireza ABDALI MASHHADI, Ahmad KOCHEKZADEH, Abdolreza SIYAHPOOSH

Department of Plant Production Engineering and Genetics, Faculty of Agriculture, Agricultural Sciences and Natural Resources, University of Khuzestan, Khuzestan, Iran

✉ Corresponding author: aminlotfi@asnrukh.ac.ir

Received: December 29, 2021; accepted: November 28, 2022

ABSTRACT

To investigate the effect of mulch and different cultivation methods on the quantitative and qualitative yield of oil sunflower (*Helianthus annuus* L.) in Ahvaz climate, a factorial experiment in randomized complete blocks with three replications in the 2017-2018 crop year was in the research farm of Agricultural Sciences and Natural Resources University of Khuzestan. The first factor includes different types of mulch in five levels (non-application, wheat straw, white plastic, live mulch (*mung bean* cultivation), and black plastic) and the second factor includes three-level cultivation method (on a flat surface, ridge cultivation, and inside the furrow cultivation). The results showed that in the flat surface and on the ridge, black plastic produced the highest amount of chlorophyll *a*, *b*, and In the inside the furrow, the highest chlorophyll *a* was obtained in the application of living mulch. The highest grain yield and oil yield were obtained from the interaction of wheat straw mulch × in the furrow and wheat straw mulch on the ridge. In addition, the highest harvest index was obtained in the treatment of white plastic mulch on a flat surface with an average of 51.85%. In general, it can be said that the treatment of wheat straw and straw × in the inside the furrow and wheat straw × on the ridge were superior in terms of quantitative and qualitative performance.

Keywords: inside furrow cultivation, in ridges cultivation, live mulch, oil yield, straw mulch

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most valuable oil plant in the world (Cechin et al., 2018) with an oil content of about 25 to 45% (Dhillon et al., 2017). Due to the suitability of agricultural needs, high levels of unsaturated fatty acids, and lack of anti-nutritional factors, the sunflower cultivation area is increasing (Kazi et al., 2002).

The sunflower during the early stages of growth is not able to create a suitable shading surface to completely prevent weeds from evaporating and growing; therefore, one of the important agronomic managements in this crop is to use a suitable cover (mulch), especially in the space between rows (Anjil Ela et al., 2014; Paul et al., 2020).

Mulching can be considered as a way to create a cover on the soil surface that is used for different purposes and perspectives. Adding mulch plays a role in maintaining soil moisture by protecting the plant from transpiration and direct evaporation from the soil surface and reduces the need for irrigation water. Wang et al., 2022 reported that maze seed yield and biomass was increased by applied mulch. The mulch reducing soil temperature and conserving more moisture and having effective on increasing water use efficiency. Reducing soil temperature, runoff, and erosion, preventing weed growth, improving soil structure, soil fertility by trapping nutrients, and preventing plants from being damaged by hot and sandy winds are among the other benefits of using

mulch (Yang et al., 2006; Baets et al., 2011). According to the research results of Abbasi et al. (2019), the use of live mulch in sunflower cultivation is of great importance.

By increasing soil moisture and root growth conditions and increasing the leaf area index, mulch improved sunflower yield and yield components compared to the treatment (no mulch application). In another experiment on sunflower, application of live and dead mulch increased grain yield by controlling weeds and improving plant growth conditions (Anjil Ela et al., 2014). Nekookhoo and Fallah (2018) reported in an experiment that the use of mulch while maintaining soil moisture increased root access to nutrients and improved oil yield in Field (*Cucurbita pepo* L.).

The sunflower cultivation method is one of the most important farming activities to achieve the maximum product. Selecting the appropriate cultivation method due to the effect on seedbed conditions, soil aeration, changing the amount of water available to the plant, and reducing competition cause changes in crop yield (Karayel et al., 2001; Awulache et al., 2009). Tong-Cha et al. (2010) in an experiment examining flat and ridge-furrow method of cultivation in China stated that cultivation in the form of inside the furrow increases water efficiency by 16.9% compared to flat cultivation and finally choosing the appropriate cultivation method can improve the product by 10 to 30%. Rana et al. (2006) in an experiment stated that due to the more effective use of environmental resources in furrow cultivation, increased water consumption efficiency and root penetration into the soil, sunflower seed yield showed a significant rise compared to flat cultivation. The results showed that maize cultivation in the middle of the furrow is superior to cultivation in the middle of the ridge in terms of improving soil salinity, soil moisture, sodium exchange capacity, seed and dry matter yield (Lak et al., 2017).

Therefore, considering the importance of oilseed cultivation in the country and the use of useful farming techniques to increase the production of these plants, the present study was conducted to investigate the effect of cultivation method and mulch application on quantitative and qualitative traits of oil sunflower.

MATERIALS AND METHODS

This experiment was carried out in the year of 2017-2018 in the research farm of Agricultural Sciences and Natural Resources University of Khuzestan located 35 km northeast of Ahvaz with an altitude of about 22 meters above sea level. The test site had been abandoned for years as Fallow. Before sowing in August, samples were taken from several points of the field to depths of 0-30 and 30-60 cm. The samples were mixed and the composite samples of each level were transferred to the soil science laboratory and then the samples were evaluated for some physical and chemical properties. The results of the soil test can be seen in table (1).

The experiment was performed as a factorial in a Randomized Complete Block Design (RCBD) with three replications. Experimental factors included mulch (non-application, wheat straw, white plastic, living mulch (*mung bean* cultivation), and black plastic) and cultivation method (on a flat surface, in the ridge cultivation, and inside the furrow cultivation). Wheat straw was selected from the remaining residues on the university farm. The straws were then weighed (15 tons per hectare (for each plot and spread evenly by hand throughout the plot. black and white plastic was used to cover the plots with plastic cover treatment. The plastics were cut to the size of each plot and spread inside the plots, then small holes were created in them with a suitable distance for planting seeds. *Mung bean* was cultivated as live mulch with a density of 15 plants per square meter in inside the furrow. Mung cultivar used to treat live mulch was an Indian cultivar. This cultivar had a growth period of about 100 days, semi-standing and with a large volume of foliage.

The dimensions of each plot were 4 × 4 meters (16 square meters) and in each plot, there were five furrow and ridges with a ridge distance of 75 cm. The distance between the plants on each ridge was 19 cm. After completing the land preparation and preparing the ridges of each plot, the seeds were planted in the middle of the ridge, inside the furrow, and on a flat surface with a depth of two to three centimetres. Then, the first irrigation was done on 31 August, and the next irrigations were done according to the needs of the plant (almost every seven

Table 1. Soil properties of experimental field

Depth (cm)	Soil texture	Silt (%)	Clay (%)	Sand (%)	ava. K (mg/kg)	ava. P (mg/kg)	Total nitrogen (%)	Electrical conductivity (dS/m)
0-30	Silt-Clay	42	41	17	124	14.43	0.026	7.32
30-60	Silt-Clay	38	43	19	140	12.35	0.013	7.98

days). The cultivated seeds in this experiment were Fantasia cultivar and intermediate cultivar prepared from Jihad Keshavarzi of Dezful city. Chemical fertilizer (NPK) as one-third of nitrogen fertilizer (70 kg pure nitrogen from urea source) with all phosphorus fertilizer (100 kg/ha from P_2O_5 source) and potash fertilizer (100 kg/ha from K_2O source) was spread in the ground before cultivation and another third of nitrogen fertilizer was applied in the pre-stem stage and the remaining third in the flowering stage as top-dressing. Weed control was performed manually in 4-5 leaf, 8 leaf, and pre-flowering stages.

After complete ripening at the time of browning behind the per head, by removing the necessary margin, to determine the quantitative traits of the plant, eight plants were harvested from one square meter, and from the harvested plants the traits of plants height, biological yield, per head weight, number of grains per square meter, 1000-grain weight, grain yield, and harvest index were measured. The concentrations of chlorophyll *a* or *b* were assessed as per methods prescribed by Arnon, 1949. About 0.5 g of fresh leaf were taken and ground with 20 ml of 80% acetone. It was then centrifuged at 10000 rpm for 20 min. After overnight extraction, the optical density (OD) of the supernatant was read using a spectrophotometer at 645 and 663 nm. The chlorophyll *a* & *b* was calculated by following formulas.

Chl *a* = 12.7A663 _ 2.69A645

Chl *b* = 22.9A645 _ 4.68A663

Soxhlet apparatus was used to measure the percentage of seed oil (A.O.C.S., 1993). To do this, the first one gram of milled sample was poured into filter paper and the weight of the sample was recorded along with the filter paper (initial sample weight). Then filter paper was then placed inside the extraction section of the machine and N-Hexane poured until the filter paper was completely immersed in the solvent. Then connect the refrigerant and turn on the heater (set the heater to 70 °C) and heat the sample for three hours. After this time, the device was turned off and the sample was placed in the oven for two hours. The sample was then cooled in a desiccator. After performing these steps, the sample weight was measured again (secondary weight of the sample) and placed in the following equation (Equation 1).

Equation (1) 100% [Primary weight of the sample / (Secondary weight of the sample - Primary weight of the sample)] = Percentage of oil

The oil yield was obtained by multiplying the percentage of oil in the grain yield. Statistical analysis of data including analysis of variance and comparison of means was performed using SAS software (9.3) and comparison of means of data was performed using LSD test at the level of 5% error probability.

RESULTS AND DISCUSSION

Chlorophyll a and b

The results of the analysis of variance showed that the interaction of mulch treatment and culture method significantly affected chlorophyll *a* and *b* (Table 2). Comparison of the mean interaction of the treatments showed that in the ridge cultivation method in black plastic mulch, the highest amount of chlorophyll *a* was obtained at the rate of 15.28 mg/g fresh weight. Also, the lowest amount of chlorophyll *a* was obtained in the same cultivation method, but in wheat straw cover at the rate of 5.97 mg/g fresh weight (Table 3). Black mulch treatment probably helps nitrogen uptake by providing a moist soil environment and thus accelerates the uptake of other constituents of chlorophyll components such as magnesium, but straw treatment reduced chlorophyll

content due to allopathic properties. Existential studies of Vojodi Mehrabani et al. (2017) in marigold showed that the application of mulch treatment was significant on chlorophyll *a* and *b* concentrations and the highest concentration was related to black mulch treatment.

Comparison of the mean interaction of cultivation method in mulch related to chlorophyll *b* showed that the cultivation method on a flat surface in black plastic mulch and non-application had the highest amount of chlorophyll *b*, which was in a statistical group within the ridge cultivation method on the same types of mulch. The lowest amount of chlorophyll *b* was obtained in the ridge cultivation method but in living mulch with an average of 2.05 mg/g fresh weight (Table 3). Chlorophyll decreased content probably occurred in living mulch due to the competition created early in the growth of the ground cover plant with the main crop. However, over time, with the positive effect of *mung bean* mulch such as nitrogen fixation, at the end of the growth period, this competition was partially offset in a way that at the end of the mulch period, it was able to create an acceptable yield among the treatments.

One of the factors that can increase or decrease the light radiation inside the vegetation is the genetic structure of the plant and the appropriate cultivation method that changes the amount of chlorophyll. Tajik et al. (2013) in studying different cultivation methods on the physiological characteristics of sunflower reported that the chlorophyll content in this plant was influenced by different cultivation methods so that the highest amount of chlorophyll was obtained from flat cultivation. It was reported that the amount of chlorophyll *a* and *b* were affected in the culture method and the highest chlorophyll *a* was obtained in the ridge cultivation method (14 mg/g fresh leaf weight) and the flat surface cultivation method was significantly lower than the other two cultivation methods (Abaslu et al., 2015).

Plant height

The effect of the cultivation and mulching method on plant height was significant but the interaction of these two factors on plant height changes was not significant (Table 2). Comparison of the average mulch treatment (Figure 1) showed that the highest plant height was related to wheat straw mulch with an average of 160 cm and the lowest plant height was related to white plastic mulch with an average of 142 cm, which with black plastic mulch was placed in the same statistical group. Probably the application of plastic mulch, by creating a higher temperature than the conditions of the straw and bare ground, caused a kind of high-temperature stress during the growing season of the sunflower. This increase in temperature led to a decrease in plant height. However, the use of wheat straw due to the lower temperature in the soil and the coolness of the soil surface improved plant growth conditions and increased plant height in comparison with other mulches.

Table 2. Analysis of variance for chlorophyll *a*, *b* and plant height of sunflower

Plant height		Chlorophyll *b*		Chlorophyll *a*		df	S.O.V.
P-Value	Sum of squares	*P*-Value	Sum of squares	*P*-Value	Sum of squares		
0.0435*	5.05	0.4258ns	0.48	0.8896ns	0.18	2	Replication
0.0235*	0.50	<.0001**	15.72	<.0001**	30.75	4	Mulch
0.0026**	0.11	<.0001**	10.12	0.0401*	5.62	2	Cultivation method
0.5088ns	0.01	<.0001**	6.55	<.0001**	16.97	8	Cultivation method×Mulch
-	0.01	-	0.54	-	1.55	28	Error
	8.03	-	16.69	-	11.82	-	C.V. (%)

*$P<0.05$ and **$P<0.01$; ns: not significant

DOI: /10.5513/JCEA01/24.1.3499

Table 3. Mean comparison for cultivation method and mulch on some characteristics of sunflower

Oil yield (t/ha)	Harvest index (%)	Grain yield (t/ha)	Weight of head (t/ha)	1000 grain weight (g)	Number of grains (m^2)	Chlorophyll *b* (mg/g)	Chlorophyll *a* (mg/g)	Mulch	Cultivation method
1.17ef	36.93c-f	4.70fg	6.32de	45.63bc	10325de	6.46ab	12.40bc	Non-application	Flat surface
1.05fg	31.48efg	4.13gh	6.25de	43.08cd	9582.13e	5.34bc	8.16gh	Wheat Straw	
1.58bc	51.84a	6.38a-d	5.49ef	51.76ab	12666abc	2.68fg	9.79efg	White plastic	
1.70b	40.64bcd	6.47abc	8.38b	47.44bc	13638a	3.93de	11.39cde	Living Mulch	
1.23def	45.66ab	5.48ef	5.83de	49.09abc	11173b-e	7.28a	14.42ab	Black plastic	
1.52bc	37.10c-f	5.99cde	8.77b	49.56abc	12132a-d	4.99cd	9.16fg	Non-application	Inside the furrow
1.71b	38.48b-e	7.21a	11.13a	55.01a	13102ab	4.07de	10.55c-f	Wheat Straw	
0.92g	26.96g	3.76h	8.06bc	37.49de	10239de	2.55g	10.45c-f	White plastic	
1.40cde	37.71b-f	5.55def	5.82de	46.14bc	12037a-d	3.87def	11.37cde	Living Mulch	
1.10fg	29.67fg	4.71fg	8.07bc	51.00ab	9258.12e	2.18g	10.22d-g	Black plastic	
1.24def	29.62fg	4.80fg	8.16b	45.10bc	10685cde	7.09a	10.32c-f	Non-application	On the ridge
2.03a	42.58bc	7.00ab	6.93cd	49.74abc	14099a	3.13efg	5.97i	Wheat Straw	
0.53h	17.92h	2.19i	4.33f	32.47e	6757.49f	4.22cde	12.16cd	White plastic	
1.51bc	39.85bcd	6.12b-e	6.83d	49.04abc	12649abc	2.05g	6.56hi	Living Mulch	
1.45cd	34.72d-g	5.38ef	6.95cd	49.38abc	11004b-e	6.65a	15.28a	Black plastic	

Means in each column and for each treatment, followed by similar letters are not significantly different at the 5% of probability level – using LSD Test

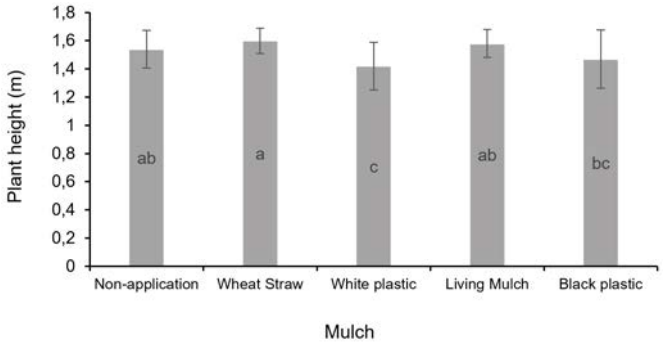

Figure 1. Effect of mulch on plant height of sunflower

In a study on sunflower, it was observed that the highest height of sunflower plant was obtained from straw treatment, which increased by 26.29% compared to the control (Mahdipour Afra et al., 2012). Also, in the study of the effect of mulch on peanuts (*Arachis hypogaea* L.), it was found that the highest plant height was obtained by applying straw mulch rather than the treatment without mulch (Ramakrishna et al., 2006).

Changes in cultivation method had a significant effect on plant height so that with inside furrow sunflower cultivation compared to in the ridge cultivation and on flat surface cultivation, plant height increased by 6.5 and 12%, respectively (Figure 2). In a study, Afsharmanesh (2014) reported that in the two-row cultivation method, with proper distribution of light within the plant community and no competition for light (due to the decomposition of auxin in the stem), the plant had less longitudinal growth; While in other cultivation methods, especially in inside furrow cultivation, due to the competition for light in the early growing season, the plants eventually had higher height.

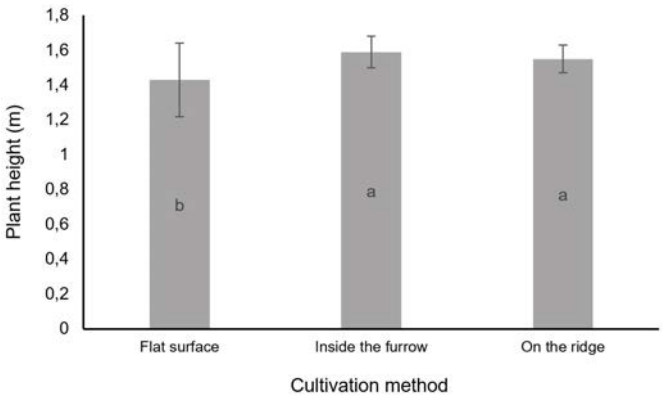

Figure 2. Effect of cultivation method on plant height of Sunflower

Number of grains

The results of the analysis of variance showed a significant effect of mulch treatment on the number of sunflower grains, however no significant difference was observed between the evacuated cultivation methods. Mulch × cultivation method was also significant on this trait (Table 4). As the comparison table shows the average interaction of factors (Table 3), in all levels of cultivation method, *mung bean* plant had the highest number of grains. Also in the Cultivation method on the ridge and in the flat surface, wheat straw mulch had the highest number of grains. There was no significant difference in the number of grains (12666 grains) in the treatment of flat surface * white plastic with the above treatments. It seems that straw and *mung bean* have been able to increase the number of grains by changing the growth of sunflower, especially in diameter per head, by creating a more suitable environment for root and plant growth. However, the plastic-coated treatments may reduce the number of grains due to unfavourable conditions such as high soil surface temperatures. In the study of Abassi et al. (2019), it was found that factors such as living mulch increase the number of grains by increasing the diameter per head.

The weight of one thousand grains

The effect of mulching and mulch interaction × cultivation method on 1000-grain weight was significant, but the cultivation method had no significant effect on this trait (Table 4). The results of Table 3 showed that, in general, plastic-coated treatments had heavier grains in all three cultivation methods, although this difference was not significant with some other treatments such as inside furrow cultivation × wheat straw mulch and in the ridge cultivation × wheat straw mulch. Plastic coated treatments probably had heavier grains due to the reduction in the number of grains (Table 3), but the wheat straw treatments also had heavier grains in the inside furrow and the ridge cultivation despite having a high number of grains, which can be said that these two treatments due to preparation very favourable condition for plant growth, produced both acceptable numbers of

Table 4. Analysis of variance for number of grains, 1000 seed weight and weight of head of sunflower

Weight of head		1000 grain weight		Number of grains		df	S.O.V.
P-Value	Sum of squares	*P*-Value	Sum of squares	*P*-Value	Sum of squares		
0.6671ns	0.20	0.0980ns	47.96	0.0583*	5851511.5	2	Replication
<.0001**	6.17	0.0008**	122.77	0.0005**	13123146	4	Mulch
<.0001**	16.86	0.2099ns	31.34	0.6663 ns	764940.5	2	Cultivation method
<.0001**	7.14	0.0004**	100.95	<.0001**	12666722	8	Cultivation method×Mulch
-	0.50	-	18.98	-	1856638.7	28	Error
-	9.87	-	9.30	-	12.07	-	C.V. (%)

*$P<0.05$ and **$P<0.01$; ns: not significant

grains and grain weight. In one study, it was reported that straw mulch produced a thousand more grains in sunflower than other ground cover plants (Mahdipour Afra et al., 2012).

Total per head weight

The results showed that the effect of all experimental factors on total per head weight was significant (Table 4). According to Table (3), mulch treatments in the inside cultivation method always had heavier per head than flat and in the ridge cultivation, so that the highest amount of total per head weight inside furrow cultivation method and wheat straw mulch treatment was obtained with the average was 11.13 tons per hectare. Finally, the lowest total per head weight was observed in the cultivation treatment on a flat surface and a ridge with white plastic soil cover. The total per head weight is strongly affected by the number of grains and the weight of the grains. Inside furrow cultivation and straw mulch due to soil moisture retention and less competition may provide better conditions for plant growth during grain formation and filling, and ultimately cause a proportional increase in grain weight and the number of grains and thus created the highest per head weight. Khodaeii et al. (2018) reported that wheat straw mulch can increase per head weight in sunflower compared to other mulches.

Grain yield

The results of the analysis of variance showed that the effect of mulching and the interaction of the two factors on grain yield were significant, but the cultivation method had no significant effect on the amount of this trait (Table 5). The method of cultivation on a flat surface, white plastic mulch, and live *mung bean* were suitable treatments to produce grain yield, while the furrow × wheat straw and the ridge × wheat straw had the highest grain yield (Table 3).

Also, the lowest total grain weight was observed in the ridge cultivation method in white plastic mulch with an average of 2.19 tons per hectare (Table 3). According to the recommendations of most previous researches, the best method of growing sunflower is in the ridge method (Fahong at al., 2004; Bakker at al., 2005; Rana at al., 2006); however, in this study, it was found that the inside furrow cultivation method can also be used as an alternative.

A noteworthy point in this study is the difference in yield with changing the type of mulch. Based on the results of Table (3) in on flat surface cultivation method, white plastic coated and living mulch was able to achieve the same yield as straw mulch inside the furrow and in the ridge cultivation methods. These factors indicate the usefulness of the flat surface cultivation depend on live mulch or white plastic which is used. However, it should be noted that due to the high price of plastic and the problems of cultivating live mulch, in sunflower cultivation, priority is still given to cultivating this crop

Table 5. Analysis of variance for grain weight, biological yield and harvest index of sunflower

Harvest index		Biological yield		Grain weight		df	S.O.V.
P-Value	Sum of squares	*P*-Value	Sum of squares	*P*-Value	Sum of squares		
0.8884ns	2.79	0.3510*	3.51	0.1520 ns	0.57	2	Replication
0.0376*	69.28	0.0075**	13.97	<.0001**	5.98	4	Mulch
<.0001**	309.63	0.0013**	27.66	0.1531 ns	0.57	2	Cultivation method
<.0001**	244.23	0.0803ns	6.54	<.0001**	6.12	8	Cultivation method×Mulch
-	23.50	-	3.23	-	0.28	28	Error
-	13.42	-	12.10	-	10.05	-	C.V. (%)

*P<0.05 and **P<0.01; ns: not significant

by inside furrow and in the bridge methods using straw mulch. Wheat straw treatment by creating suitable growing conditions for the plant caused plants with higher height and more grains per square meter than other treatments leads to increasing grain yield. Hossini et al. (2012) showed that the treatment of sunflower mulching increased the total grain weight, which was consistent with the results of this experiment. On the other hand, *mung bean* as living mulch could not create a good grain yield compared to straw in inside furrow and in the ridge cultivation method. This result is probably because the ground cover plant itself has competed with the crop for environmental resources, and thus, by removing the resources from the crop's reach, there has been a decline in yield (Latifi et al., 2015).

Biological Yield

The results showed that the effect of mulch and cultivation method on biological yield was significant, but the interaction of the two factors had no significant effect on biological yield (Table 5). The study of the effect of mulch on the biological yield of sunflower showed that wheat straw mulch with 16.13 tons per hectare produced the highest biological yield, which in this regard were at the same level with live and control mulch treatments and compared with white plastic, Increased biological yield by 25.23% (Figure 3). Live mulch and straw may have been able to increase biological yield due to moisture retention and the positive effect of mulch, but plastic mulch, despite the positive effect of mulch due to high temperature in the growing season, had more negative effects on plant life that in whole provided the basis for the decline in biological performance. In the study of the effect of mulch on biological yield in beans, it was observed that mulch had an additive effect on biological yield; So that the biological yield in the cover plant treatment was significantly higher than treatment with no cover plant (Amini et al., 2015).

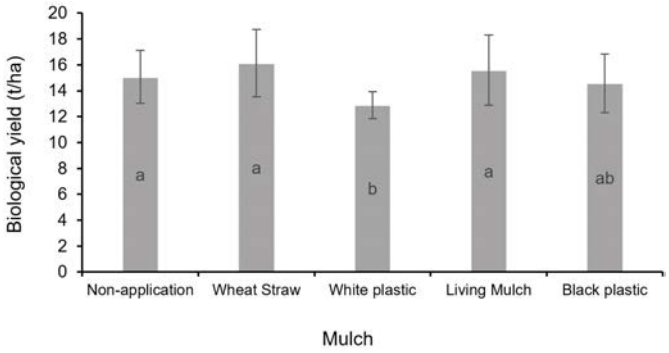

Figure 3. Effect of mulch on biological yield of Sunflower

An optimal cultivation method improves the canopy arrangement and maximizes plant weight by creating suitable competitive conditions such as optimal nutrient uptake. In the present experiment, the method of cultivation on a flat surface produced a lower rate of biological yield than the other two methods. As inside furrow cultivation increased the biological yield by 18% compared to the cultivation on a surface (Figure 4).

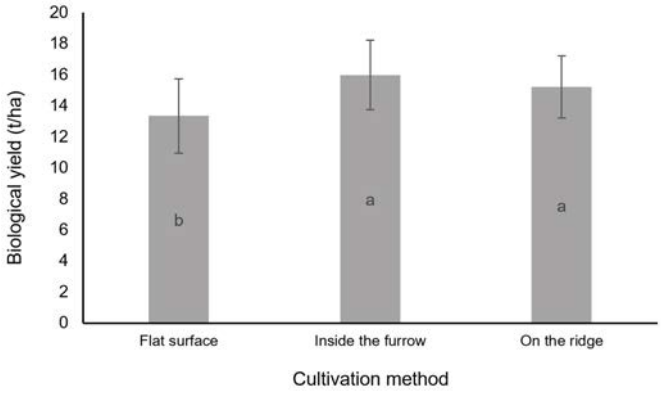

Figure 4. Effect of cultivation method on biological yield of Sunflower

Because in inside furrow cultivation and the ridge treatment, water is better available to the plant than on cultivation on a flat surface, and this leads to better access to nutrients for the plant, so more water and nutrients are available to the plant by increasing plant height, dry weight of grains and leaves of plants increases biological yield (Sarmadnia and Koocheki, 2003).

Harvest index

The results showed that the effect of all experimental factors on the harvest index was significant (Table 5). In general, the highest harvest index (51.84%) was obtained from flat surface cultivation treatment with white plastic mulch, although it was not significantly different from black plastic mulch. Also, in the inside furrow and the ridges cultivation, the highest harvest index was related to straw mulch (Table 3). Given that the harvest index is dependent on biomass yield and grain yield and indicates the ratio of photosynthetic material distribution between economic yield and biological yield, it seems that a greater increase in grain yield than biological yield in the treatment of cultivation on a flat surface of white plastic increases harvest index in this treatment. In other words, more photosynthetic material is transferred to the reproductive organs and less is spent on vegetative growth and production of stems and structural tissues (Abassi et al., 2019). It has been reported that plastic mulch due to reduced water evaporation from the soil surface, with less water consumption, can cause higher grain yield than biological yield and thus a higher harvest index (Yi et al., 2010).

Oil yield and percentage

The results of oil percentage and yield showed that oil percentage was not affected by cultivation method and mulching and their interaction; however, oil yield was affected by mulch and cultivation method interaction ($P < 0.05$) (Table 6). The results showed that the highest percentage of oil yield was obtained from the ridge cultivation × wheat straw. In flat surface cultivation with the use of all mulch except white plastic, the oil yield decreased compared to the other two cultivation methods (Table 3). Since the oil yield is obtained by multiplying the percentage of oil in the grain yield, in this experiment the oil yield was affected more than the oil percentage by grain yield and the in the ridge cultivations and Inside furrow cultivation treatment

Table 6. Analysis of variance for oil content and oil yield of sunflower

Oil yield		Oil content		df	S.O.V.
P-Value	Sum of squares	*P*-Value	Sum of squares		
0.0981 ns	503.43	0.0123*	278.40	2	Replication
<.0001*	1865.10	0.0738 ns	16.67	4	Mulch
0.9135 ns	117.20	0.2917 ns	8.60	2	Cultivation method
<.0001*	1020.62	0.1342 ns	4.22	8	Cultivation method × Mulch
-	395.75	-	12.15	28	Error
-	20.11	-	14.10	-	C.V. (%)

*$P<0.05$ and **$P<0.01$; ns: not significant

with straw mulch, due to higher grain yield, they were able to get the first and second rank among treatments in terms of oil yield. It seems that on the one hand, the use of wheat straw due to increased plant access to water and nutrients increased the number and yield of grain and thus oil yield, and on the other hand, in the ridge cultivation or inside furrow, with positive effects such as reducing salinity and preventing crusting and better absorption of nutrients paved the way for increased oil yield. Finally, the application of inside furrow cultivation and wheat straw treatment simultaneously resulted in the highest oil yield (Nekookhoo and Fallah, 2018).

CONCLUSION

The results of this research showed that in the flat surface, black plastic produced the highest amount of chlorophyll *a*, *b*, number of seeds, seed yield and oil yield. In the inside the furrow, the highest chlorophyll *a* was obtained in the application of living mulch. However, in the same cultivation method, the highest seed and oil yield, chlorophyll *b* content and harvest index were obtained in wheat straw. In the on the ridge, the highest amount of chlorophyll *a*, *b* was created in black plastic, but the highest seed yield, seed number harvest index and oil yield were obtained in straw mulch. Using the results of this project, it can be concluded that mulch treatment and appropriate cultivation method by affecting plant growth conditions and providing plant access to environmental resources, increase grain yield and oil yield. Considering access to of wheat straw mulch, in comparison with other types of mulch its use in the conditions of Khuzestan plain can be recommended in sunflower agriculture. Also, based on the obtained results, the inside furrow cultivation method can be proposed as an alternative to ridge cultivation.

ACKNOWLEDGMENT

Agricultural Sciences and the Natural Resources University of Khuzestan is appreciated for its assistance in conducting this research.

REFERENCES

A.O.C.S. (1993) Official methods and recommended practices of the American oil chemist`s society, 5th edition, Ba 6-48. The American Oil Chemist`s Society.

Abaslu, L., Kazemeini, S., Edalat, M., Dadkhahi, A. (2015) Effect of drought stress and planting method on some physiological and biochemical characteristics of two chickpea cultivars. Journal of Crops Improvement, 16 (4), 933-943. Persian. DOI: https://doi.org/10.22059/jci.2015.53587

Abassi, B., Mohammad, G., Bagheri, A. (2019) Effect of living mulch on grain yield, yield components and some morphological traits of Sunflower (*Helianthus annuus* L.) cultivars. Journal of Agricultural Science and Sustainable Production, 29 (3), 13-25.

Afsharmanesh, G. (2014) Effect of planting pattern on grain yield and agronomic traits of corn cultivars in Jiroft, Iran. Applied Field Crops Research, 27 (102), 124-130. Persian. DOI: https://dx.doi.org/10.22092/aj.2014.100938

Amini, R., Dabbagh Mohammadi Nasab, A., Ghalandarzade, E. (2015) Effect of mulch and water stress on some physiological traits, yield components and grain yield of red Kidney bean (*Phaseolus vulgaris* L.). Iranian Journal of Field Crops Research, 13 (4), 687-699. DOI: https://doi.org/10.22067/gsc.v13i4.30532

Anjil Ela, M., Yousefi, A., Poryusof, M., Fotovat, R. (2014) Study on Weed Management in Sunflower using Buckwheat (*Fagopyrum esculentum* Moench) as Living and Dead Mulch. The Journal of Field Crop Sciences, 44 (4), 613-621. DOI: https://doi.org/10.22059/IJFCS.2013.50331

Arnon, D.I., (1949) Copper enzymes in isolated chloroplasts. Polyhenoloxidases in Beta vulgari. Plant Physiology, 24, 1-15. DOI: https://doi.org/10.1104/pp.24.1.1

Awulache, S.B., Lemperiere, P., Tulu, T. (2009) Irrigation methods: Surface irrigation Options for smallholders. Addis Abeba: International Livestock Research Institute (ILRI), 168-203.

Baets, S.D.E., Poesen, J.J., Meersmans, J.J., Serlet, L.L. (2011) Cover crops and their erosion-reducing effects during concentrated flow erosion. Catena, 85, 237-244. DOI: https://doi.org/10.1016/j.catena.2011.01.009

Bakker, D. M., Hamilton, G. J., Joulbrooke, D. J., Spamn, C. (2005) The effect of raised beds on soil structure, water logging, and productivity on duplex soils in Western Australia. Australian Journal of Soil Research, 43, 575-585. DOI: https://doi.org/10.1071/SR03118

Cechin, I., Gonzalez, G.C., Corniani, N., Fumis, T.F. (2018) The sensitivity of sunflower (*Helianthus annuus* L.) plants to UV-B radiation is altered by nitrogen status. Journal of Ciencia Rural, 48 (2), 1-6.

Dhillon, B.C., Sharma, P.K., Sharma, S., Sharma, S. (2017) Oil yield and fatty acid composition of spring sunflower as affected by sowing date, intra row spacing and nitrogen dose. Indian Journal of Agricultural Biochemistry, 30 (2), 135-140.

Fahong, W., Xuging, W., Sayre, K., (2004) Comparison of conventional flood irrigated flat planting with furrow irrigated raised bed planting for winter wheat in china. Field Crops Research, 87, 35-42.

Hossini, M., Zamani, Gh., Alizadeh, H.M., Eslami, S.V. (2012) Evaluation effect of different wheat residue and sunflower densities on growth and yield of sunflower. Journal of Crop Production, 4 (3), 37-53. DOI: https://dorl.net/dor/20.1001.1.2008739.1390.4.3.3.9 (in Persian with English abstract).

Karayel, D., Brut, Z.B., Ozmerzi, A. (2001) Mathematical modelling of vacuum pressure ona precision seder. Biosystems Engineering, 29 (1), 199-111.

Kazi, B.R., Oad, F.C., Jamro, G.H., Jamali, L.A., Oad, N.L. (2002) Effect of water stress on the growth, yield and oil content of sunflower. Pakistan Journal of Applied Sciences, 2 (5), 550-552.

Khodaei, F., Abdali Mashhadi, A., Lotfi Jalal Abadi, A., Koochekzadeh, A. (2018) Effect of mulch and selenium and boron foliar spraying on some quantitative and qualitative characteristics of Sunflower (*Helianthus annuus* L.) in saline soil. Journal of Crop Production, 11 (3), 43-59. DOI: https://doi.org/10.22069/ejcp.2019.14410.2092 (in Persian with English abstract).

Lak, S., Dashti, H., Abadoz, Gh. (2017) Assessment Water Consumption and planting pattern on edaphic soil properties and grain yields of corn in Khuzestan province. Journal of Plant Ecophysiology, 8 (4), 114-126.

Latifi, S., Yousefi, A., jamshidi, K. (2015) Interaction effect of cultivar and living mulch on sunflower yield and weed control. Journal of Crops Improvement, 17 (2), 415-430. DOI: https://doi.org/10.22059/jci.2015.55190 (in Persian with English abstract).

Mahdipour Afra, R., Amiri, R., Iran Nejad, H. (2012) Effect of polyethylene and organic mulches in different intervals of irrigation on morphological characteristics and grain yield of sunflower (*Helianthus annus* L.). Agroecology, 4 (3), 246-254. DOI: https://doi.org/10.22067/jag.v4i3.15313 (in Persian with English abstract).

Nekookhoo, M., Fallah, S. (2018) Effect of deficit irrigation and nitrogen on fruit, grain, and oil yield of hull-less seed pumpkin (*Cucurbita pepo* L.) under plastic mulch. Iranian Journal of Medicinal and Aromatic Plants Research, 34 (2), 245-260. DOI: https://doi.org/10.22092/ijmapr.2018.110622.2030 (in Persian with English abstract).

Paul, P.L.C., Bell, R.W., Barrett-Lennard, E.G., Kabir, M.E. (2020) Straw mulch and irrigation affect solute potential and sunflower yield in a heavy textured soil in the Ganges Delta. Agricultural Water Management, 239, 106211.

Ramakrishna, A., Tam, H.M., Wani, S.P., Log, T.D. (2006) Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. Field Crop Research, 95, 115-125. DOI: https://doi.org/10.1016/j.fcr.2005.01.030

Rana, M. A., Arshad, M., Masud, J. (2006) Effect of basin, furrow and rain gun sprinkler irrigation systems on irrigation efficiencies, nitrate-nitrogen leaching and yield of sunflower. Pakistan Journal of Water Resources, 10, 1-7.

Rana, M.A., Arshad, M., Masud, J. (2006) Effect of Basin, Furrow and Rain gun Sprinkler Irrigation Systems on Irrigation Efficiencies, Nitrate-Nitrogen Leaching and Yield of Sunflower. Pakistan Journal of Water Resources, 10, 1-7.

Sarmadnia, G., Koocheki, A. (2003) Crop Physiology. Mashhad: Jihad Daneshgahi Publication. (in Persian)

Tajik, M., Takli, A., Yousefi, A., Nikbakht, J. (2013) The study of the surface effect of water and blossoming on the performance and physiological characteristics of sunflower. Master's thesis. Zanjan University.

Tong-Cha, W., Wei, L., He-Zhou, W., Shou-Chen, M., Ma, M. (2010) Responses of rainwater conservation, precipitation-use efficiency and grain yield of summer maize to a furrow-planting and straw-mulching system in northern China. Field Crops Research, 161, 669-690. DOI: https://doi.org/10.1016/j.fcr.2011.06.014

Vojodi Mehrabani, L., Valizadeh Kamran, R., Azizpour, K. (2017) The effects of organic manures, soil cover and drying temperature on some growth and phytochemical characteristics of Calendula officials. Journal of Agricultural Science and Sustainable Production, 26 (4), 103-112.

Wang, C., Wang, J., Zhang, Y., Qin, S., Zhang, Y., Liu, C. (2022) Effects of different mulching materials on the grain yield and water use efficiency of maize in the north China plain. Agriculture, 12, 1112. DOI: https://doi.org/10.3390/agriculture12081112

Yang, Y.M., Liu, X.J., Li, W.Q., Li, C. (2006) Effect of different mulch materials on winter wheat production in desalinized soil in Heilongjiang region of North China. Journal of Zhejiang University Science, 7 (11), 858-867.

Yi, L., Shenjiao, Y., Shiqing, L., Xinping, C., Fand, C. (2010) Growth and development of maize (*Zea mays* L.) in response to different field water management practice: Resource capture and use efficiency. Agricultural and Forest Meteorology, 150, 606-613. DOI: https://doi.org/10.1016/j.agrformet.2010.02.003