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Correlation Analysis of Yield and Yield Components in Sunflower (*Helianthus annuus* L.) Cultivars under Different Leaf removal

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ABSTRACT

The present investigation was conducted in the educational-researching farm of Islamic Azad University, Miyaneh branch during the growing season of 2014 and 2015 to evaluate the effects of different treatments of leaf removal on different characteristics such as yield and yield components in two early maturing cultivars of sunflower, Megasun, and Hayson36. The experiment design was factorial based on randomized complete block design with 3 replications. In addition, shrub morphological and physiological characteristics, shrub dry weight, chlorophyll contents, leaf area index (LAI), harvesting index (HI), and oil yield were studied. The results showed a significant difference between various treatments of defoliation, yield components, and studied traits. Moreover, no statistically significant difference was observed between the cultivated cultivars in the study parameters including the head diameter, chlorophyll content, LAI, HI, the 1000-grain weight, seedlessness percentage, and seed and oil yield. In this experiment, the interaction effect of different defoliation treatments and cultivars with studied traits other than the head diameter, chlorophyll contents, HI, seed number, and the 1000-grain weight were not significantly different. The correlation coefficients traits reduce grain and oil yield treatments to remove the whole leaves in the middle one-third reduction stems from two factors filled grain percentage and grain is 1000. That appears to reduce the performance of treatment discontinuation in the middle one-third more affected seed weight in 1000 is located. In conclusion, this study revealed that damage to leaves at the flowering stage of sunflower, in particular, leaves from the top or the middle of the plant due to biotic and abiotic factors decreased seed and oil yield.

Keywords: *Correlation, Leaf removal, Sunflower, Characters, Seed and oil yield.*

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1. INTRODUCTION

In sunflower, leaves are the site of photosynthetic functions, which are necessary for seed filling. Removing leaves from the plants (or decreasing their number) results in the reduced efficacy, making the plant vulnerable to damage caused by pest, disease, mechanical damage, and hail. Loss of leaves also causes depreciation of photosynthetic material to transfer to the seeds and ultimately decreases the seed filling percentage, grain weight, and yield. Leaf removal experiments simulate these damages due to the above-mentioned causes. These experiments showed that the role of leaves, that is the supply and transfer of photosynthetic material, extends to other parts of the plant, specifically the stem. Additionally, it was found that leaf removal during the sensitive growth stage caused by undesirable environmental and climatic factors has an important impact on farm management (Anonymous, 2007). The studies also showed that yield loss caused by the leaf damage was low at the complete seed formation stage and even at later stages, the leaf damage had no effect on seed yield. Therefore, partial damage to leaves at the development stage had no effect on the plant's ability to produce yield. According to a study, when the leaves of soybean were completely removed in the middle stage of growth and at the complete growth stage, the yield was reported to reduce by 81% and 6%, respectively. It was also reported that yield reduction caused by leaf removal was affected by the specific growth habit of the plant. The complete removal of leaves in indeterminate cultivars at the development stages before complete seed formation decreases yield. Whereby, yield decrease means for determinate and indeterminate cultivars were 59% and 39%, respectively (Barimavandi, Sedaghathoor and Ansari, 2010). Cultivars with semi-determinate habits showed more yield decrease than indeterminate cultivars in experiments to test the effects of leaf removal. The most sensitive periods of sunflower growth are the flowering and seed filling stages. During the seed filling stage, low temperature, light deficiency, damage from diseases, pests, and water shortage decrease photosynthetic materials and subsequently generative growth is restricted. Changes in the seed-filling period affect yield and yield components. The results of experiments dealing with the effects of leaf removal on seed yield in sunflower showed that if leaves were removed near the flowering stage, the yield loss was high due to reduced photosynthesis (Kene and Charjan, 1999). In those experiments, the highest yield loss was obtained with 100% leaf removal, which was determined by weight loss of 1000

grains and seed number in the head (Muro *et al*., 2001). The experiment showed that the leaves on the middle of the plant had a more important role in seed yield than leaves on other parts of the plant, indicating that the middle leaves have high photosynthetic activity (Kamath, Guggari and Basavarajappa, 1992). Different leaf removal treatments affect oil yield and its percentage. In addition, the leaf removal at the specific developmental stage affects oil yield and its percentage. Since oil synthesis begins after the flowering stage and continues until the leaves are active, leaf removal at this stage has the greatest impact on oil yield and seed oil percentage (Alliari, Shikari and Shikari, 2000). Reports do exist about the importance of sunflower leaves and their phyllotaxy on seed oil percentage; Turner, (2006) reported that the removal of top leaves resulted in lower oil percentage (Turner *et al*., 2006). The purpose of this study was to determine the effects of artificial leaf removal on the yield and yield components of two hybrids, Megasun and Haysun36 are in Miyaneh climatic condition.

2. MATERIALS AND METHOD

The field experiments were conducted at the educational-researching farm, Miyaneh branch, Islamic Azad University, (latitude 47042N, longitude37024E, altitude 1100m) during the growing season of 2014 and 2015. The soil was calcareous and had a clay-loam texture with a pH of 7.5. The experiment design was factorial based in a randomized complete block design with 3 replications. The factors under investigation were two sunflower cultivars; Megasun and Hysun36, and 5 leaf removal treatments, 0%, 33% down, middle, top, and 100% leaves (control) at the flowering stage of sunflower. The land preparation began in the autumn of 2013 until April 2013 and planting was carried out in May 2014 and 2015. The required fertilizers were used based on soil chemical analysis and subsequent recommendations of the Miyaneh Water and Soil Research Institute. Then the five-leaf removal was made. Chlorophyll content per plant and head diameter was measured. In order to determine the dry matter weight, 10 plants were selected from the 2 middle rows in each plot and dried at 70-75°C for 48h, using a ventilated oven. Then the dried plants were weighed. Seed yield and biological yield for the 2 middle rows were determined and then Harvest Index (HI) was measured using the following expression:

Harvest index = Seed yield / Biological yield

The unfilled seed percentage, the 1000-grain weight, and the seed number per head with five-leaf removal were measured. In order to extract the oilseed, the moisture content of the seeds was reduced by 10%, the seeds were dried at 40°C for 4h, using a ventilated oven. They then were ground with a Warring Blender. Four grams of the ground seed was used for oil extraction with petroleum ether for 6h in a Soxhlet system. The oil extract was evaporated by distillation at reduced pressure in a rotary evaporator at 40°C until the solvent was completely removed. All data were subjected to an analysis of variance (ANOVA) test and the treatment means were separated with Duncan's multiple range tests at 1 % level in MSTAT-C.

3. RESULTS AND DISCUSSION

The different leaf removal treatments had a significant effect on chlorophyll content, LAI, and HI; the effect of leaf removal on shrub dry matter was significant and the interactions between leaf removal and cultivar on chlorophyll content and shrub dry matter were significant. The results showed that the levels of shrub dry matter, chlorophyll content, LAI, and HI in the Megasun cultivar were higher than the Hysun36 cultivar (Figure 1). Leaf removal of 33% from the middle, and non-leaf removal (control) treatments showed a significant difference in the shrub dry matter, chlorophyll content, LAI and HI compared to the leaf removal treatments. These results indicated that leaves in the middle of the plant had an important role in photosynthesis because they were clearly responsible for 60-80% of photosynthesis and their removal affected the total shrub dry matter, chlorophyll content, LAI, and HI; therefore, the final weight of dry matter declined. Thus, the distribution of the dry matter between vegetative organs of the plant is crucial not only for the formation of the final product but also for the growth rate of the plant (Barimavandi, Sedaghathoor and Ansari, 2010). The difference among field plant species is mainly due to the difference between the rates of photosynthesizing matter conversion to dry matter. Principally, dry matter distribution in each part of the plant is as equally important as the dry matter production (Table 1).

Table 1. Mean comparison of dry matter per plant, chlorophyll content, leaf area, Index, harvest index.

Treatment	Dry matter per plant		Chlorophyll rate		Leaf area index		Harvest index	
Year / **Cultivar**	2014	2015	2014	2015	2014	2014	2014	2015
Megasun	145.58a	154.25a	31.49a	33.35a	2.54a	2.74a	32.03a	31.12a
Haysun 36	123.92a	136.2oa	28.87b	29.17b	2.36b	2.07b	26.73b	24.88b
Leaf removal								
Non (control)	172.17a	179.33a	39.36a	40.96a	3.37a	3.36a	34.73a	34.12a
From one third of up	167.23ab	179.55a	38.50ab	38.88a	3.010b	3.56b	30.40a	29.21a
From one third of middle	122.03b	130.11b	34.04b	33.04b	2.640c	2.98c	27.04b	24. 65b
From one third of down	173.36a	185.43a	39.50a	38.66a	3.249a	3.56a	33.13a	32.76a
All	36.37c	43.78c	0.00c	0.00c	0.000d	0.000d	21.54b	19.89b

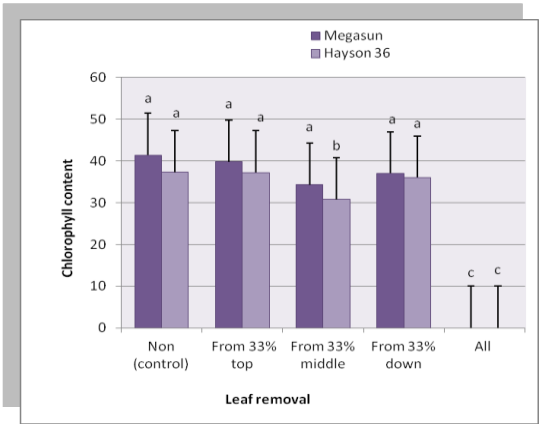
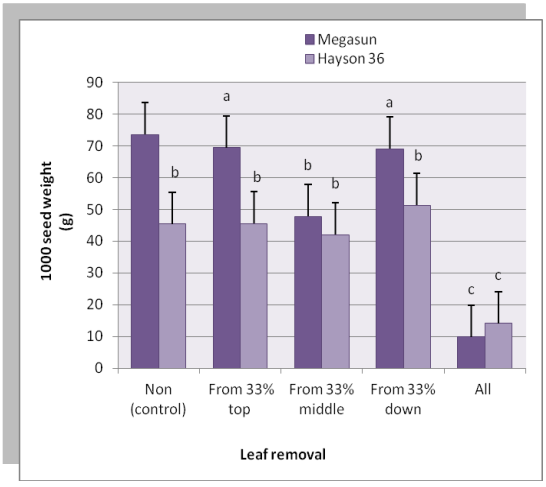


Figure 1. The interaction between leaf removal and chlorophyll content.

Cultivars and different leaf removals had significant effects on the results including the 1000-grain weight, unfilled seed percentage, seed yield, and oil yield. The effect of leaf removal was also significant on the seed number in the head. Whereas, the interaction between the cultivars and leaf removal had no significant effect on any of the studied traits other than seed number in the head (Figure 2). As shown in Table 2, there was a significant difference in the seed yield statistics between different cultivars and leaf removals, where Megasun cultivar and leaf removal treatments of 0% and 33% from the lower part of the plant had the highest yields. Seed yield in sunflower with different leaf removal, 100 and 33% middle, as well as top and down, decreased 87, 47, 35, and 5%, respectively compared to the control. These results indicated that the leaf removal from the top and middle of the plant due to the subsequent loss of photosynthetic activity near the plant head caused a decreased seed yield. It is also noteworthy that leaves on the top 33% of the plant in relation to the lower 33% have an important role in filling the physiologic sinks. Loss of photosynthesis and reduction of photosynthetic material for transportation as a consequence of leaf removal reduce seed yield (Borrás and Otegui, 2001). This study showed that seed yield reduced with leaf removal and it was related to the plant growth stage when the leaves were removed (Muro *et al*., 2001; Johnson, 2003). Leaf removal increased the number of unfilled seed in the flower head (Table 2.). Muro *et al.*, (2001) reported that leaf removal at the pollination stage increased the number of unfilled seed and subsequently seed yield reduced. As presented in Table 2, the results from the means comparison showed that leaf removal decreased the total number of seeds compared to the control.

Table 2. Mean comparison for the number of seed in the head, 1000-grain weight, unfilled seed, and seed and oil yield.

Treatment	No. of seed in the head		1000 seed weight (g)		Unfilled seed (%)		Seed yield (ton)		Oil yield (ton)	
Yare / Cultivar	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Megasun	1137.08a	1137.08a	54.31a	53.93a	5.123b	19.83b	3.91a	3.19a	1.74a	1.75a
Haysun 36	1096.16a	1096.16a	45.82b	41.67b	11.510a	22.77a	3.1b	2.4b	1.57a	1.36b
leaf removal										
Non	1320.10a	1320.10a	54.27a	59.52a	4.908d	6.03c	4.77a	3.90a	2.26a	1.88a
From one third of up	1074.73bc	894.50ab	47.42b	52.47b	7.715c	8.50c	3.62b	3.28ab	1.67ab	1.42b
From one third of middle	989.500c	719.00bc	40.81c	44.91c	13.915b	11.50b	2.43c	2.15b	1.11ab	1.02b
From one third of down	1224.16ab	976.17ab	53.98a	60.16a	4.927d	8.53c	4.31ab	3.68a	2.11a	1.80a
All	850.187c	581.50c	25.52d	16.945d	66.333a	70.33a	0.49d	0.53c	0.26c	0.11c



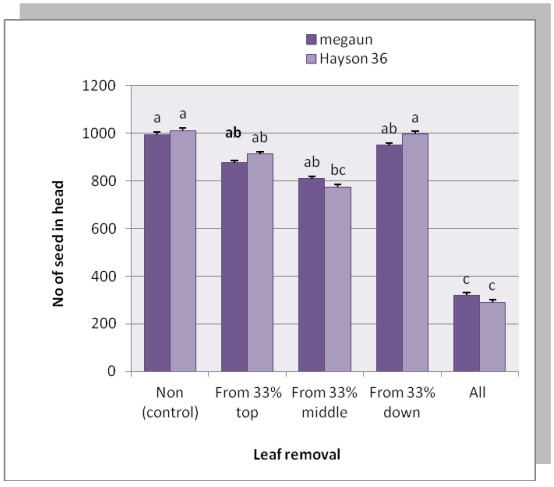


Figure 2. Interaction defoliation and cultivar with seed number in the head and 1000-seed weight.

Removal of leaves from the top 33% at the flowering stage had the highest decrease in the 1000-grain weight compared to the other treatments (Table2). As presented in Table 2, the results obtained from means comparison showed that 0% and 33% lower down defoliation treatments had higher oil yields compared to the other treatments, because oil synthesis in sunflower begins after the flowering stage approximately 3 days after fertilization and continues until the leaves are active, therefore leaf removal at this stage has the highest impact on oil yield. Several studies have been done on the importance of sunflower leaves and their position and effect on oil percentage, for example, one study reported that defoliation from the of top of the plant resulted in lower oil percentage (Patil and Goswami, 1979).

Correlation of Traits Related to Yield

The head diameter, seed number, 1000-seed weight, and HI were the traits, which were effective in the changes of seed yield and oil yield (Table 3). The decrease in the head diameter did not significantly lower the seed number. The negative correlation between the head diameter and seed number in treatments also proved the same fact. However, a decrease in the head diameter in the middle one-third of the stem leaf removal treatment and complete leaf removal treatment in comparison to the control treatment caused a more significant decrease in the seed number. The correlation between the head diameter and seed number in these two treatments indicated the same fact. It seemed that yield decline was mainly affected by their position in the seed number in upper one-third of the stem defoliation treatment but middle one-third leaf removal and complete leaf removal treatments led to a decline in 1000-seed weight, seed number, and yield. Additionally, the relation between the seed yield and oil yield resulted in the same trend in its changes.

Table 3. The correlation of cultivar and defoliation such as treatment.

Head	1									
Dry matter per plant diameter	**0.90	1								
Chlorophyll rat	**0.90	**0.91	1							
Leaf area index	**0.90	**0.93	**0.98	1						
Harvest index	**0.83	**0.68	**0.70	**0.68	1					
No. of seed in the head	**0.78	**0.70	**0.65	**0.64	**0.82	1				
1000-seed weight	**0.87	**0.92	**0.88	**0.90	**0.73	**0.54	1			
Unfilled seed	**0.48-	**0.63-	**0.78-	**0.77-	0.25-	0.27-	**0.57-	1		
Seed yield	**0.86	**0.93	**0.87	**0.88	**0.80	**0.74	**0.91	**-0.61	1	
Oil yield	**0.84	**0.91	**0.85	**0.86	**0.77	**0.72	**0.89	**-0.62	**0.99	1

* and **: significant at 5 and 1 percent level, respectively.

4. CONCLUSION

Results demonstrated that higher levels were recorded from the Megasun cultivar for them from the Hysun36 cultivar. Removal of leaves of 33% from the middle and non-defoliation (control) treatments showed a significant difference than other defoliation treatments. Cultivars and different levels of leaf removal had significant effects on the results. There was a significant difference in the seed yield statistics between different cultivars and leaf removals, where Megasun cultivar and leaf removal treatments of 0% and 33% from the lower part of the plant had the highest yields. Seed yield in sunflower with different leaf removal, 100 and 33% middle, as well as top and down, decreased 87, 47, 35, and 5%, respectively compared to the control. These results indicated that the removal of leaves from the top and middle of the plant caused a decreased seed yield due to the subsequent loss of photosynthetic activity near the head of the plant. It is also noteworthy that leaves in the top 33% of the plant play an important role in filling the physiological sinks. The correlation coefficients traits reduce grain yield and oil treatments to remove the whole leaves in the middle one-third reduction stems from two factors filled grain percentage and grain is 1000. That appears to reduce the performance of treatment discontinuation in the middle one-third more affected seed weight in 1000 is located.

In conclusion, this study revealed that damage to leaves at the flowering stage of sunflower, in particular leaves on the top or middle of the plant due to biotic and abiotic factors decreased seed and oil yield.

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