Chapter 2

The Effect of Leaf Removal–Based Physical Injury on High Seed and Crude Oil Yields in Sunflower (*Helianthus annuus* L.)

Mustafa Yildiz, Mehdi Taher, Marieh Javani,
Ramazan Beyaz and Mehtap Gursoy

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.71357

Abstract

Yield in agricultural production decreases due to biotic (diseases and pests) and abiotic (salinity, drought, high temperature, etc.) stress factors. Chemical methods have been widely used to fight against biotic stress factors. However, the use of chemicals in agriculture causes extra financial cost and environmental pollution. Improvement of high yielded cultivars via plant breeding methods does not seem to be adequate for meeting food demand of increasing population. That is why, the improvement of environmentally friendly new methods for high yield is obligatory. Leaves in plants form an active surface for photosynthesis. High photosynthetic activity affects yield directly by increasing matter production. The aim of this study was to increase seed and oil yields in sunflower via leaf defoliation. Oil-type sunflower cultivars used in the study, “08-TR-003,” “TR-3080,” and “TARSAN-1018,” were obtained from the “Trakya Agricultural Research Institute.” When plants reached to “star-shaped head stage,” which is the beginning of the reproductive period, four different defoliation treatments were performed. They were control (no leaves removed), two leaves removed, four leaves removed, and six leaves removed. Half of the leaves were removed from just below the head, while the other half was removed from the middle part of the plant. After harvest, seed yield per plant, seed yield per decare, crude protein percentage, crude oil percentage, crude protein yield per decare, and crude oil yield per decare were determined. At the end of the study, it was observed that the application of defoliation, compared to the control, affected all characteristics positively.

Keywords: Sunflower, defoliation, seed yield, crude protein yield, crude oil yield

1. Introduction

Plants comprise the source of life on earth. In total, 90% of the energy and 80% of the protein consumed by humans are of plant origin. The remaining energy and protein requirements are met by animal products. Thousands of people die every year in many parts of the world due to hunger and malnutrition. It is necessary to increase crop production so that human beings can feed on a sufficient and balanced diet to sustain their existence on Earth. This can only be achieved by increasing the amount of yield obtained from each unit area of land, since it is not possible to further increase existing cultivating areas.

It is estimated that world population will increase by 1.5% per year to 8 billion in 2020 and 11 billion in 2050 [1]. The area of land covering the Earth is 14 billion hectares. Currently, 10% of this land area is cultivated. About 20% of the world's land is covered with pastures, 20% with mountains, 20% with glaciers, and 20% with deserts. The remaining 10% of the area has a very shallow soil cover. Given the impossibility of agricultural activities in mountains and glacier-covered areas, there are areas of potential agriculture, such as marshlands, deserts, or areas with insufficient land cover. It is largely impossible to use pastures that cover rugged and very sloping areas as cultivating fields. The conversion of deserts and inadequate land cover into agricultural land requires great investment.

In parallel with increasing population, agricultural areas are being used for other nonagricultural purposes (settlement, road, factory, etc.) or are shrinking rapidly due to erosion, salinization, acidification, intensive agriculture, and overgrazing. It is estimated that agricultural land per capita, which is now 0.26 hectares, will decrease to 0.15 hectares by 2050. In addition, the availability of water resources for modern agriculture will become difficult due to increased water consumption and increasing water pollution [1]. It is expected that food requirements in the most populous parts of the world will double by 2025 [1].

The yield in agricultural production declines due to biotic and abiotic stress factors. Developing a resistant or tolerant cultivar against these stress factors is the main goal of plant breeding. Chemical methods are commonly used to combat biotic stressors (diseases and pests) that reduce crop production. However, the use of chemicals in agriculture causes an extra financial burden and pollutes the environment. In Turkey, 2.3 million tons of chemical fertilizer and 25,000 tons of pesticides (insecticides, fungicides, and herbicides) were used according to the data from 2013. In the last 25 years, it has emerged that the unconscious use of fertilizers and chemicals applied in plant production has negatively affected long-term ecological balance. For example, it has been determined that overused nitrogen fertilizers are washed from the soil and pollute drinking water and the seas, while the nitrogen components that are escaping from the gaseous state are adversely affecting the ozone layer, which protects the earth from harmful rays of the sun. In addition, herbicides and insecticides applied to combat weeds and pests have been shown to destroy the natural equilibrium in agricultural areas, causing the emergences of new diseases and pesticides. It has also been understood that certain chemicals, which have permanent effects, accumulate in plants, and this negatively affects the health of people and animals fed on those plants. As a result, it is

http://dx.doi.org/10.5772/intechopen.71357

not possible to increase the crop production by using more chemical fertilizers and pesticides in the future.

On the one hand, the world population is increasing day by day, and on the other hand, the limits of agricultural land have been reached; it is clear that yield increases still need to continue into the future [2].

Two types of sunflower are grown in Turkey and the rest of the world for oil production and for producing snacks. The production of sunflower oil in Turkey is mostly concentrated in the Trakya-Marmara region, while the production of sunflowers for snacks is mostly carried out in the Central and Eastern Anatolia regions. Oil-type sunflowers are generally black colored, thin-crusted, with 38 to 50% oil and 20% protein in their seeds. Sunflower oil has one of the highest nutritional values among vegetable oils because it contains a high percentage of polyunsaturated fatty acids and a low proportion of saturated fatty acids.

Highly efficient genotypes are used to increase the yield in a unit area of land. Chemical fertilization is carried out, and chemical treatments are applied to combat the diseases and pests that cause yield losses in large quantities. However, it is possible to increase the production to a certain degree by using high-yielding cultivars, fertilizing and applying chemicals where necessary. Development of new plant cultivars resistant to biotic and abiotic stress factors by using plant breeding (classical and modern) methods is a difficult task, because the resistance to these stress factors is caused by more than one gene (additive gene effect). Therefore, the development of environmentally friendly new methods to enhance crop production is extremely important.

In plants, the leaves form the active surface for photosynthesis. The high level of photosynthetic activity also increases the production of substances [3, 4]. In our greenhouse trials, it was observed that defoliation, to a certain level, increased metabolic activity and photosynthetic activity. In sunflower, "star-shaped head stage" is the beginning of the flowering and fertilization period (the reproductive period) followed by the formation of seeds. After this cycle, substances formed as a result of photosynthesis are stored in the seeds. High levels of photosynthetic activity in this stage will increase the production of the material in the leaves and will increase important agricultural characteristics such as seed yield, crude protein yield, and crude oil yield.

In the study conducted by Taher et al. [5], seed yield and crude oil yield have been increased significantly by defoliation of the leaves forming the surface for photosynthesis. By the use of the production method described in this study, the amount of crude oil needed in Turkey has been reduced and the large amount of money currently paid for imports was decreased significantly.

2. Materials and method

The study conducted by Taher et al. [5] was carried out in the research fields of the Faculty of Agriculture, Ankara University in the years of 2013 and 2014. Oil-type sunflower cultivars

Figure 1. Sowing plan for sunflower cultivars according to the "randomized complete block, split-plots" design with three replications.

"08-TR-003," "TR-3080," and "TARSAN-1018" obtained from "Trakya Agricultural Research Institute" were used in the study. Soil of trial field was plowed 30 cm in depth in fall before winter. In spring, it was plowed again for 10–15 cm in depth to make soil ready for sowing. Sowing was performed in the first week of April with spaces of 70 cm inter-row and 25 cm on-row. Three seeds were put in each dibbling to guarantee the emergence. Two weeks after emergence, two of the plants were eliminated and only one plant left in each dibbling. For all defoliation treatments, plots were fertilized with 14 kg/da diammonium phosphate (DAP) before sowing. During growing, weed control was achieved by hand in experimental field. The study sowing plan is given in **Figure 1**.

When plants reached to "star-shaped head stage," which is the beginning of reproductive period, defoliation was carried out and the plants were labeled. Half of the leaves were removed from just below the head, while the other half was removed from the middle part of the plant for each defoliation treatment (**Figure 2**). Four different defoliation treatments were performed. They were:

- First treatment (Control): Defoliation was not carried out in this case.
- Second treatment: A total of two leaves were removed from the plant. One of these leaves was selected from the below of the head, and the other from the middle of the plant.

http://dx.doi.org/10.5772/intechopen.71357

- Third treatment: A total of four leaves were removed from the plant. Two of these leaves were taken from the below of the head, and the other two were taken from the middle of the plant.
- Fourth treatment: A total of six leaves were removed from the plant. Three of these leaves were selected from the below of the head, and the remaining three from the middle of the plant.

Plants were irrigated during development according to water need of the plants. During the application of irrigation, the most attention was given to watering each parcel equally. After the flowering and fertilization has been completed, the heads of the plants from which the measurements were taken were covered with paper bags to protect the seeds from damage by birds (**Figure 3**). Plants were harvested when 80% of sunflower heads were brown.

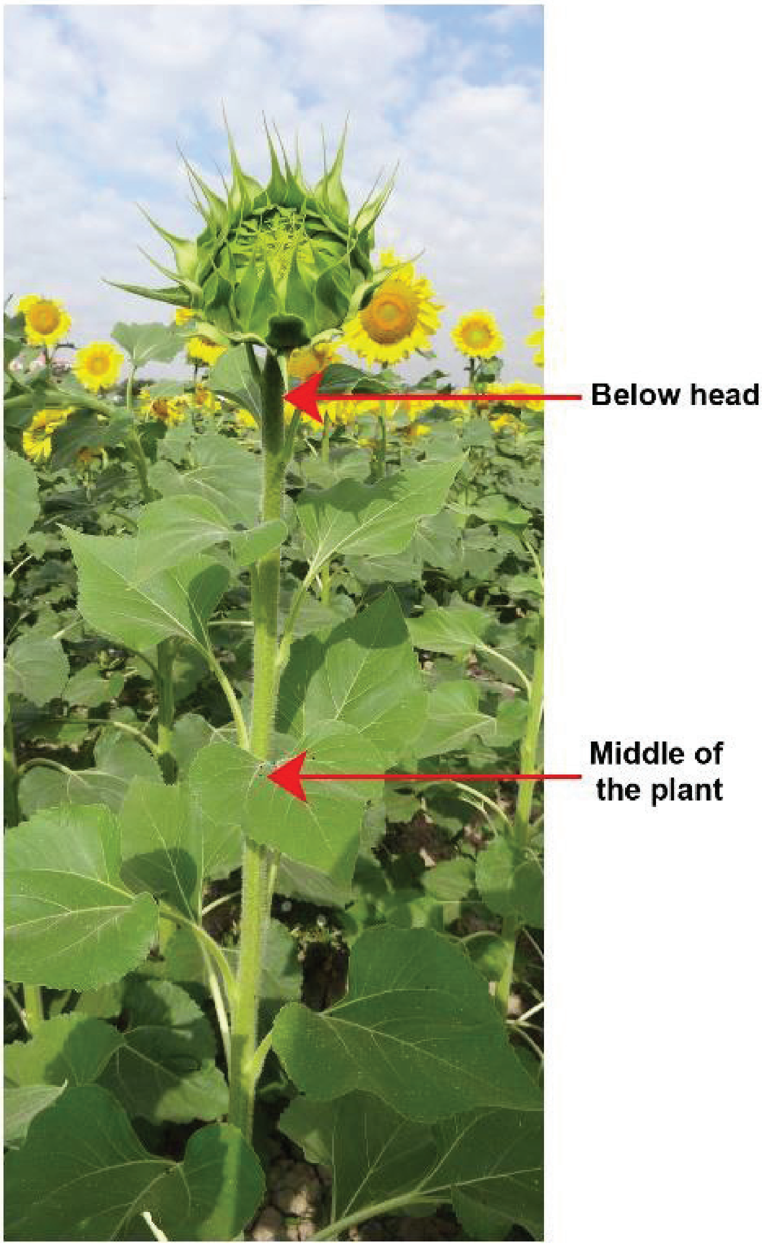

Figure 2. The places from where leaves were removed in “star-shaped head stage” (from below the head and from the middle of the plant).

Figure 3. Flowering in the head (on the left) and covering the head with paper bags to protect seeds from bird's damage (on the right).

Measurements were performed in totally 30 plants (10 plants per replication) in each defoliation treatments in all cultivars. Seed yield per plant (g/plant), seed yield per decare (kg/decare), protein and oil percentages, crude protein, and crude oil yields (kg/decare) were recorded.

Experiments were arranged at "randomized complete block, split-plot" design with three replications. In the experiment, oil-type sunflower cultivars were main plots and four defoliation applications were subplots. Data were statistically analyzed by Duncan's multiple range test using "IBM SPSS Statistics 22." Data given in percentages were subjected to arcsine ($\sqrt{X}$) transformation before statistical analysis [6].

3. Results and discussion

There are research studies examining the effects of defoliation on seed and crude oil yields in sunflower. However, in all these studies, it was reported that leaf removal from plant gave rise to decreases in seed yield and crude oil yield. It was thought that these negative results were caused by the incorrect and incomplete application of the methods used in those researches. In some studies, all leaves in plant were removed [7–9], while 1/3 or 2/3 of leaves were removed in some other ones [9, 10]. Or defoliation was carried out in the lower, middle, and upper leaves of the plants [11, 12]. It was reported that effective leaves on yield were in top and middle of the plant [13]. In our study, a certain amount of defoliation (0 = control,

http://dx.doi.org/10.5772/intechopen.71357

two, four, and six leaves removed) was carried out in the middle of the plant and from the below of the head in "star-shaped head stage," which is the beginning of the reproductive period in the plant, and the results of photosynthesis are assimilated and transported to the seeds. When the amount of assimilation produced by photosynthesis is increased, the seed yield will also directly increase.

In this study, on the effects of different defoliation treatments on seed, crude protein, and crude oil yields per decare in "star-shaped head stage," which is the beginning of the reproductive period in sunflower, it was determined that different defoliation treatments, according to cultivars, significantly increased seed, crude protein, and crude oil yields compared to the control group with no defoliation treatment (**Table 1**).

For cv. "08-TR-003," the seed yield per decare was 385.4 kg in the control treatment in which no leaf was removed, while it was 431.2 kg in the four-leaf defoliation treatment in the plant. This means that the yield increased by 11.87%. An increase of 1.90% was observed in the crude protein yield obtained from a decare. When the oil yield per decare value was examined, it was 175.0 kg for the control treatment, while it was 207.7 kg — an increase of 18.67% — in the four-leaf defoliation group. The highest values for seed, crude protein, and crude oil yields in the cv. "08-TR-003" were obtained when four leaves per plant were removed (**Table 1**).

In cv. "TR-3080," the seed yield per decare in control treatment was measured as 398.3 kg, whereas there was an 8.64% increase to 432.7 kg when two leaves were removed at the beginning of the reproductive period. The protein yield was 66.2 kg in the control, whereas it increased by 6.40% up to 70.4 kg when two leaves were removed. Examining the crude oil yield per decare values, it was 184.8 kg for the control treatment, whereas it increased by 13.36% to 209.5 kg when two leaves were removed from the plant. In cv. "TR-3080," the highest values for seed, crude protein, and crude oil yields were obtained from the two-leaf defoliation treatment (**Table 1**).

In cv. "TARSAN-1018," 407.3 kg/da seed yield determined for the control treatment was 451.6 kg/da when six leaves were removed from the plant. This indicates that in the six-leaf defoliation treatment, seed yield increased by 10.87% compared to the control. Crude protein yield per decare was found to be 75.6 kg for control treatment, while it was 85.1 kg for the six-leaf defoliation, an increase of 12.61%. The crude oil yield per decare value in the control group was 190.7 kg, while it was 215.3 kg for the six-leaf defoliation treatment, with an increase of 12.92%. In cv. "TARSAN-1018," the highest values for seed, crude protein, and crude oil yields were obtained from the six-leaf defoliation treatment (**Table 1**).

Leaves forming the surface for active photosynthesis in plants can be damaged due to environmental factors (such as storms and hail) and mechanical factors (tools and machines used in maintenance operations such as drilling and spraying). The extent of this damage is directly proportional to the amount of defoliation. In other words, as the number of defoliations increases in the plant, the agricultural characteristics decrease proportionally, based on the cultivar. This is confirmed by the lowest values for the seed yield per decare values obtained in our study for the six-leaf defoliation treatments for cvs. "08-TR-003" and "TR-3080."

Cultivars	Defoliation treatment	Seed yield (g/plant)	Seed yield (kg/da)	The increase in the seed yield compared to control (%)	Crude protein percentage (%)	Crude protein yield (kg/da)	The increase in the crude protein yield compared to control (%)	Crude oil percentage (%)	Crude oil yield (kg/da)	The increase in the crude oil yield compared to control (%)
"08-TR-003"	0 (Control)	70.1 ± 0.68 c	385.4 ± 3.74 c	11.87	18.2 ± 0.41 a	70.4 ± 1.12 a	1.90	45.4 ± 1.49**a**	175.0 ± 4.16 c	18.67
	2	67.6 ± 0.85 d	371.9 ± 4.68 d		16.7 ± 0.38 a	62.8 ± 1.10 b		46.7 ± 0.63**a**	173.1 ± 1.08 c	
	4	78.4 ± 0.28 a	431.2 ± 1.52 a		16.6 ± 0.56 a	71.7 ± 1.25 a		48.3 ± 0.45**a**	207.7 ± 1.18 a	
	6	72.6 ± 0.72 b	399.0 ± 3.97 b		16.9 ± 0.49 a	68.2 ± 0.53 ab		46.5 ± 0.50**a**	185.1 ± 1.84 b	
"TR-3080"	0 (Control)	72.4 ± 0.10 b	398.3 ± 0.57 ab	8.64	16.7 ± 0.76 a	66.2 ± 0.75 b	6.40	46.3 ± 1.32**a**	184.8 ± 1.47 b	13.36
	2	78.7 ± 0.82 a	432.7 ± 4.50 a		16.3 ± 0.41 a	70.4 ± 0.67 a		48.4 ± 0.44**a**	209.5 ± 1.60 a	
	4	70.6 ± 0.69 b	388.1 ± 3.77 b		17.5 ± 0.17 a	67.7 ± 0.81 b		47.6 ± 1.34**a**	184.7 ± 2.06 b	
	6	68.5 ± 1.00 c	376.6 ± 5.51 b		15.7 ± 0.03 a	59.2 ± 1.13 c		46.3 ± 1.79**a**	173.8 ± 1.29 c	
"TARSAN-1018"	0 (Control)	74.1 ± 0.80 b	407.3 ± 4.41 b	10.87	18.6 ± 0.72 a	75.6 ± 0.86 c	12.61	46.8 ± 0.46**a**	190.7 ± 1.32 c	12.92
	2	77.3 ± 0.42 b	425.3 ± 2.30 ab		18.1 ± 0.34 a	77.1 ± 0.90 c		46.9 ± 0.26**a**	199.7 ± 1.67 bc	
	4	80.6 ± 0.24 ab	443.4 ± 1.30 a		20.3 ± 0.09 a	81.0 ± 1.02 b		46.4 ± 0.25**a**	206.0 ± 5.96 b	
	6	82.1 ± 0.10 a	451.6 ± 1.20 a		18.9 ± 1.31 a	85.1 ± 0.77 a		47.8 ± 1.29**a**	215.3 ± 1.46 a	
Mean				10.46			6.97			14.98

The difference between the averages indicated by different letters in the same column is statistically significant at the 0.01 level.

Table 1. The effect of different defoliation treatments on seed yield per plant, seed yield per decare, crude protein percentage, crude protein yield, crude oil percentage, and crude oil yield in sunflower (*Helianthus annuus L.*).

Considering the general average values of the three cultivars used in this study, seed yield increased by 10.46%, crude protein yield increased by 6.97%, and crude oil yield increased by 14.98% compared to the control group when defoliation treatment was applied in "star-shaped head stage," which is the beginning of the reproductive period.

4. Economic analysis

In 2014, we estimated that the Turkish population was 77,695,904 [14] and that annual consumption of vegetable oil per capita should be 21 kg, corresponding to 1,630,000 tons of vegetable oil needs. Accordingly, 800,000 tons of this was met with domestic production, and a shortage of 835,000 tons of crude oil was identified [15]. In 2014, 795,000 tons of crude oil was obtained from sunflower.

Turkey paid 1194 US dollars for importing 1 ton of vegetable crude oil in 2014, and 835,000 tons of crude oil met by imports would be 996, 990,000 US dollars [15]. In 2014, oil-type sunflower seeds were sown over an area of 5,524,651 decares in Turkey and 1,480,000 tons of sunflower seeds were produced; the seed yield was 269.00 kg/da [16]. The crude oil yield in the sunflower was 143.90 kg/da.

According to the results obtained in this study, when leaves are reduced in sunflower cultivation, the seed yield per decare will increase from 269.00 to 297.13 kg, a 10.46% increase, and the crude oil yield will increase from 143.90 to 165.95 kg, a 14.98% increase. This means that crude oil production in Turkey from sunflower will be 914,054 tons (165.45 × 5,524,651). In other words, when the method described in the current study based on defoliation is applied to the production of sunflower, the production of crude oil in Turkey will increase to 119,054 tons (914,054–795,000). Considering that 1194 US dollars was paid for 1 ton of crude oil import, it is seen that 142,150,476 dollars (119,054 × 1194) will be retained domestically by applying the method developed in our research.

5. Conclusion

Due to the increasing world population and the rapid consumption of natural resources, there is a need to increase crop production. Aside from increasing the agricultural lands to increase crop production, existing agricultural lands are decreasing day by day. In this case, it is necessary to develop new high-yielding cultivars and to apply agricultural techniques (fertilization, irrigation, and agricultural pest control) as the best way to increase crop production. However, with the rapidly increasing world population and ever-narrowing areas available for agriculture, the development of new cultivars resistant to biotic and abiotic stress factors (extreme heat, extreme cold, salinity, new pest culprits, and pest breeds) is extremely difficult due to time limitations and to the resistance characteristics being under the control of more than one gene. Therefore, it is necessary to develop new methods in order to increase the yield per unit area for plants that play an important part in human nutrition (wheat, corn, rice, sunflower, etc.).

With this research, it has been shown that crop production can be increased by physiological stimulation of plants. In greenhouse researches, it has been determined that reduction in the photosynthetic surface, through a certain number of defoliations in the plant, results in an increase in photosynthetic activity in the remaining leaves of the plant, which causes significant increases in the agricultural characteristics.

Using the method developed in this research, decreasing the number of leaves at the beginning of the reproductive stage in sunflower plant has resulted in significant increase in agricultural characteristics such as seed yield, crude protein yield, and crude oil yield. Thanks to this developed environmentally friendly production method, an increase of about 120,000 tons of crude oil production has been achieved in sunflower. The developed method can be successfully used in other plants to increase the crop production.

Author details

Mustafa Yildiz[1]*, Mehdi Taher[2], Marieh Javani[2], Ramazan Beyaz[3] and Mehtap Gursoy[4]

*Address all correspondence to: myildiz@ankara.edu.tr

1 Department of Field Crops, Faculty of Agriculture, Ankara University, Ankara, Turkey

2 Department of Field Crops, Graduate School of Natural and Applied Sciences, Ankara University, Ankara, Turkey

3 Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Ahi Evran University, Kırsehir, Turkey

4 Aksaray University, Guzelyurt Vocational School, Aksaray, Turkey

References

[1] Vasil IK. Biotechnology and food security for 21st century: A real-world perspective. Nature Biotechnology. 1998;**16**:399-400

[2] Özcan S, Yıldız M, Mirici S, Sancak C. Transgenic plant technology. In: Turkey 3rd Field Crops Congress. Adana, Turkey; December 15-18, 1999. p. 11-16

[3] Nelson JC. Genetic associations between photosynthetic characteristics and yield: Review of the evidence. Plant Physiology and Biochemistry. 1988;**26**:543-554

[4] Richards RA. Selectable traits to increase crop photosynthesis and yield of grain crops. The Journal of Experimental Biology. 2000;**51**:447-458

[5] Taher M, Javani M, Beyaz R, Yildiz MA. New environmental friendly production method in sunflower for high seed and crude oil yields. Fresenius Environmental Bulletin. 2017;**26**(6):4004-4010

http://dx.doi.org/10.5772/intechopen.71357

[6] Snedecor GW, Cochran WG. Statistical Methods. Iowa, USA: The Iowa State University Press; 1967

[7] Johnson BJ. Effect of artificial defoliation on sunflower yields and other characteristics. Agronomy Journal. 1972;**64**:688-689

[8] Periera ASR, Rodrigues AS. Effect of leaf removal on yield components in sunflower. Netherlands Journal of Agricultural Science. 1978;**26**:133-144

[9] Butignol CA. Sunflower yield with three different stages of artificial defoliation. Pesquisa Agropecuaria Brasileria. 1983;**18**:631-634

[10] Fleck NG, Silva PRF, Machado CMN, Schiocchet MA. Artificial defoliation during and anthesis stage of sunflower. Pesquisa Agropecuaria Brasileria. 1983;**18**:371-379

[11] Erbaş S, Baydar H. Defoliation effects on sunflower (*Helianthus annuus* L.) seed yield and oil quality. Turkish Journal of Biology. 2007;**31**:115-118

[12] Aljobori KMM, Aldirach F. Effect of leaves defoliation and date of defoliation on growth of sunflower plant (*Helianthus annuus* L.) in gypsyferous soil. Irak Science Journal. 2009; **50**(4):445-457

[13] Sackston WE. Effects of artificial defoliation on sunflowers. Canadian Journal of Plant Science. 1959;**39**(1):108-118

[14] TURKSTAT. Turkish Statistical Institute Press Releases, No: 18619; 2015

[15] Anonymous, 2015. Bitkisel Yağ Sanayicileri Derneği, www.bysd.org.tr

[16] TURKSTAT. Turkish Statistical Institute Press Releases. Crop Production Statistics. 2015

IntechOpen