Journal of Agricultural Science; Vol. 15, No. 5; 2023
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Investigation of the Effect of Thermal Tension in Hot Seasons and Interruption of Irrigation at the End of the Growth Season by Silicon Nutrient Solution Sulfonated With S8 Elemental Sulfur on Fresh and Dry Fodder Yield and Protein Content of Alfalfa (*Medicago sativa* L.)

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Received: February 20, 2023 Accepted: March 19, 2023 Online Published: April 15, 2023

doi:10.5539/jas.v15n5p40 URL: https://doi.org/10.5539/jas.v15n5p40

Abstract

This research is an introduction to the combined nutrient of mineral salts by Silicon sulfonated with S8 through aerial organs of the Alfalfa plant. This type of combined nutrition by S8 is called “Matrix Nutrition”. This experiment was launched in October 2022 to study the effect of S8 on increasing the yield of fresh and dry fodder and the percentage of Alfalfa protein content using combined nutrition or Matrix Nutrition on the aerial organ of Alfalfa plant in the condition of interruption of irrigation at the end of the growing season in Moghan region, Ardabil province in Iran. The experiment was carried out in 2 plots, each one being one-hectare land. (In the first plot, S8 was applied for 5 litres per 1000 litres of water in the growth stages as foliar spraying after each crop harvest. No S8 was applied in the second plot.) The 5th and 6th harvests coincided with a dry season in this region and no irrigation was applied in this experiment for the 5th and 6th harvests. Both plots were only irrigated similarly for 1st to 4th harvest. The results obtained from a total of 5 harvests of the Hamedani Variant Alfalfa plant in the Control Plot and 6 harvests of the Hamedani Variant Alfalfa plant in the Experiment Plot indicated the highest yield in the 1st plot treated with S8 in terms of fresh and dry fodder, percentage of dry materials of fodder and protein content with a significant difference of 1% and 5% compared to Control Plot. The difference between the two plots was: fresh fodder 11,610 Kgs/Hectare, *i.e.*, 91.27% higher yield, dry fodder 4,099 Kgs/Hectare, *i.e.*, 140.95% higher yield, increase in dry material percentage for 5.99% and higher protein content of fodder for 1.59% which indicated a significant positive effect of application of S8 nutrient solution as foliar spraying on the increase of yield in fresh and dry fodder in the growing season and specifically at the time of thermal tension (specifically on 2nd and 4th harvest in control plot on June and August) and interruption of irrigation at the end of growth season (5th and 6th harvest of experiment plot).

Keywords: S8, Matrix Nutrition, wet fodder yield, dry fodder yield, protein content, dry material percentage, Alfalfa

1. Introduction

Nowadays, water shortage is one of the most important factors limiting crops in arid and semi-arid areas. Alfalfa is the most important fodder plant that is consumed as fresh and dry fodder. Alfalfa is a plant with high tolerance against draught (Kaya et al., 2005). Alfalfa is a drought-resistant plant with the ability to tolerate long-term draught during the growth season period and is one of the few crops that could revive after receiving enough moisture. Drought conditions have several effects on pre-dormant Alfalfa, firstly, it causes a reduction of yield and change of quality and, secondly, affects the ability of the plant to survive in the winter. Irrigation and plant management during periods of drought and shortage of water resources can have a significant impact on yield, crop quality and survival capability of the plant (Edvard & Ag, 2005). The application of silicon increases plant yield (Kaya et al., 2006). Silicon produces antioxidant enzymes (Kaya et al., 2006) and causes resistance against cold and hot weather (Wang et al., 2016). Gerami and Torabipour (2022) reported that silicon increases resistance to heat and cold tensions and dehydration. Faridi Maivan et al. (2018), Yousefi et al. (2019), Zink (1996), Westermann and Tindall (1998), Franzen et al. (2017), Dave and Jerome (2021), Noble (2022), and Dia (2022) reported that potassium compounds increase yield and tolerance to dehydration, cold and disease. Ansuri et al. (2014) reported that the sulfur causes an increase in yield and decreases soil Ph. Hassan Panah et al. (2022a, 2022b) reported that S8 increases the yield in the plant, S8 in two forms of foliar spraying (with a concentration of 4 per thousand) and irrigation (in the amount of 5 litres of S8 in 200 litres of water) increases the function of the tuber in the potato root and reduces its water consumption. Hassan Panah et al. (2022) concluded that the application of an S8 nutrient solution increases plant height and water consumption efficiency. This research aims to increase the yield of fresh and dry fodder, the percentage of Alfalfa protein content during the growth period under thermal tensions during the hot months of the year (June-August) and interruption of irrigation at the end of the growth season (5^{th} and 6^{th} harvest) by application of S8 with Matrix Nutrition technique in Moghan region of Ardabil province in 2022.

2. Method

The experiment was carried out in 2 plots of one-hectare land with two treatments. (The first plot includes the application of S8 nutrient solution in the amount of 5 litres/1000 litres of water in the growth stages after each harvest as foliar spraying and the second plot was cultivated without the application of S8 nutrient solution.) During the growth period in Experiment Plot, S8 solution foliar spraying was applied once in each harvest (7-10 days after each harvest). In the first 4 harvests in treatment and Control Plots, irrigation was applied in similar ways. No irrigation was applied in the 5th and 6th harvests. Hamedani variety with proper purity and germination rate and weed free was used for cultivation. 12 kgs of seeds per hectare were used and the experiment was done in the 2nd year after cultivation. S8 nutrient solution contained 50% sulfur, 2% silicon, 20% Potassium, 3% magnesium, 3% calcium, 2% nitrogen, 2500 ppm iron, 200 ppm zinc, 250 ppm boron, and 300 ppm manganese. The yield characteristics of fresh and dry fodder, the percentage of dry material of the fodder and the percentage of the protein content of the fodder were measured during the growth period and after harvest and the treatment and Control Plots were compared by t-test with possibility rate of 5%.

3. Results and Discussion

The results obtained from the total harvest of the treatment and Control Plot of the Hamedani variety indicate that the highest yield of fresh and dry fodder, the highest percentage of dry material of fodder and the highest percentage of the protein content of fodder were related to the application of S8 nutrient solution and the treatment of using the solution. Yield differences are as follows: fresh fodder 11,610 Kgs/Hectare, *i.e.*, 91.27% higher yield, dry fodder 4,099 Kgs/Hectare, *i.e.*, 140.95% higher yield, increase in dry material percentage for 5.99% and higher protein content of fodder for 1.59%. This yield increase indicates a significant positive effect of the S8 nutrient solution applied during the growing season in thermal tension in June and August (2nd and 4th harvest) and also interruption of irrigation at the end of growth season (5th and 6th harvest).

Table 1. Average of fresh fodder yield in Control Plot (Without the application of S8)

Harvest	Harvest date	Harvest amount
1^{st} harvest	12 May 2022	3650 kg/Hectare
2^{nd} harvest	10 Jun 2022	2820 kg/Hectare
3^{rd} harvest	14 Jul 2022	3230 kg/Hectare
4^{th} harvest	17 Aug 2022	2020 kg/Hectare
5^{th} harvest	22 Oct 2022	1000 kg/Hectare
Total harvest		**12720 kg/Hectare**

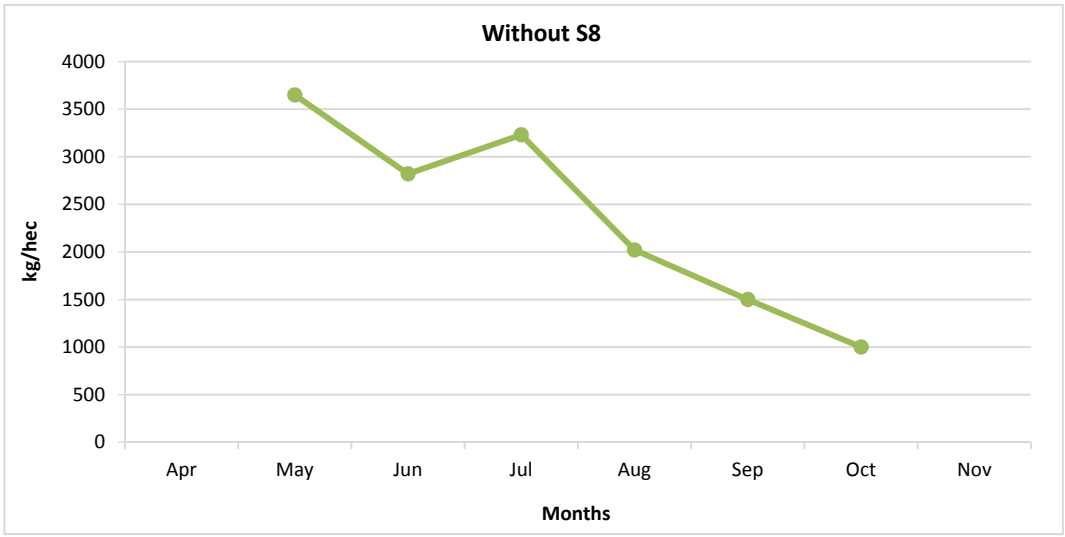


Figure 1. Diagram of the monthly harvest of Alfalfa in the Control Plot (Without the application of S8)

Table 2. Average of fresh fodder yield in Experiment Plot (Treated with S8)

Harvest	Harvest date	Harvest amount
1st harvest	23 Apr 2022	4800 kg/Hectare
2nd harvest	31 May 2022	4880 kg/Hectare
3rd harvest	30 Jun 2022	5160 kg/Hectare
4th harvest	03 Aug 2022	4210 kg/Hectare
5th harvest	13 Sep 2022	2780 kg/Hectare
6th harvest	22 Oct 2022	2500 kg/Hectare
Total harvest		**24330 kg/Hectare**

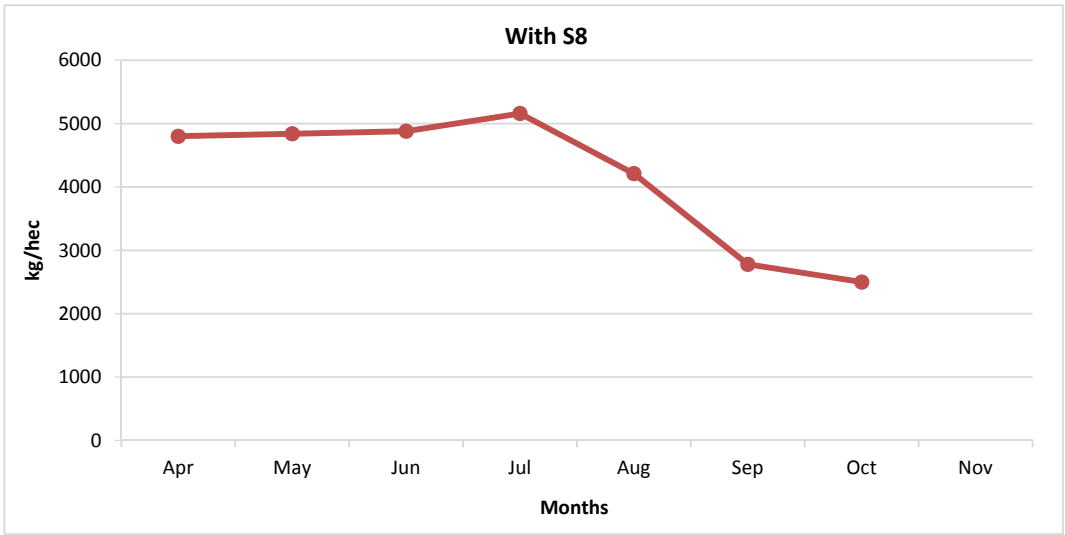


Figure 2. Diagram of the monthly harvest of Alfalfa in Experiment Plot (Treated withS8)

Table 3. Comparison of yield in Control and Experiment Plot

Treatment	The total harvest of fresh fodder (Kgs/Hectare)	The total harvest of dry fodder (Kgs/Hectare)	Dry material of fodder (%)	The protein content of fodder (%)
S8	24330	7007	28.88	19.4
Control Plot	12720	2908	22.89	17.81
Treatment	11610	4099	5.99	1.59

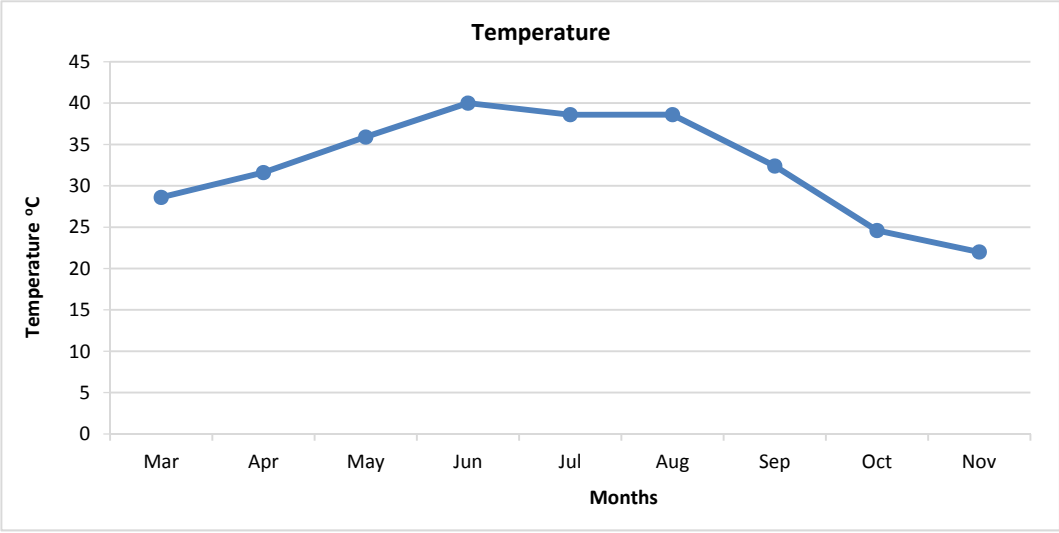


Figure 3. Diagram of climatology data (Absolute Maximum Temperature)—2022

Table 4. Climatology date for 8 months in Pars Abad (Moghan)—2022

Parameter	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Average Monthly Temperature	12.6	17.8	23.9	27.5	27.3	24.1	20.3	12.6
Absolute Minimum Temperature	-2.4	0.6	9.2	12.8	15.3	13.6	8.3	2.2
Absolute Maximum Temperature	28.6	31.6	35.9	40	38.6	38.6	32.3	24.6
Number of days with Temperature above 35 °C	0	0	3	15	12	3	0	0

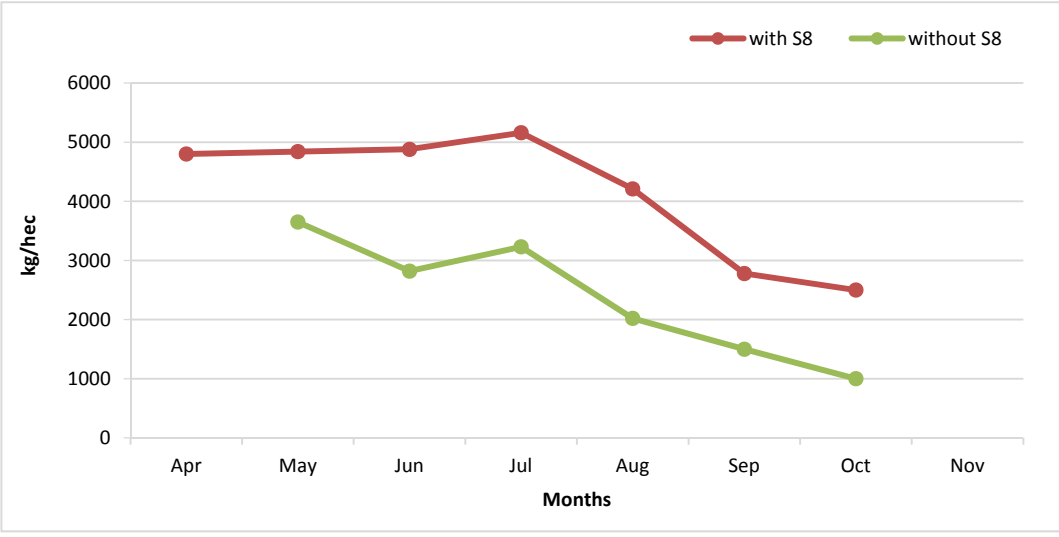
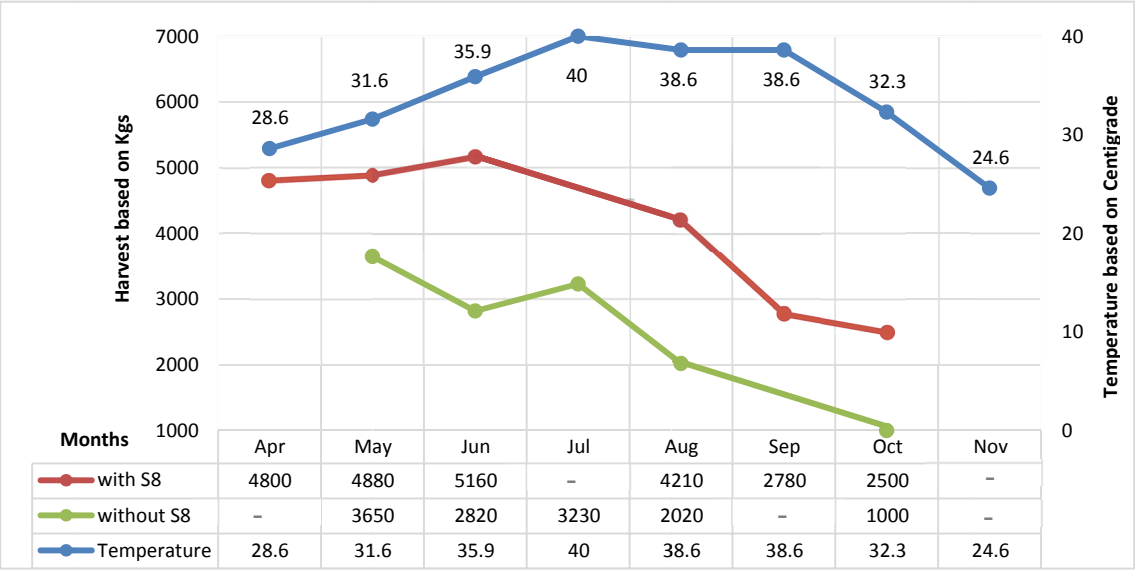


Figure 4. Comparison of monthly harvest in control and Experiment Plot



Months	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
with S8	4800	4880	5160	-	4210	2780	2500	-
without S8	-	3650	2820	3230	2020	-	1000	-
Temperature	28.6	31.6	35.9	40	38.6	38.6	32.3	24.6

Figure 5. Comparison of harvest in Control and Experiment Plot in terms of monthly Temperature

3.1 Results

Based on the data in Figure 5 which compares the amount of harvest in control and experiment plot in terms of monthly temperature, the results for Matrix Nutrition or combined nutrient by S8 in thermal tension during hot months of the year (June-August) resulted in 3 harvests in experiment plot (treated with S8) equal to 14,840 Kgs/Hectare and 3 harvests in control plot for 8,070 Kgs/Hectare which indicates an increase in yield and significant difference of 176.6%. It is to be noted that based on the climatology data presented in Table 4, thirty (30) days with a temperature of above 35 °C and an average temperature of 38.16 °C have been recorded during the said 3 months. Water shortage at the end of the cultivation season and water tension in the 5th and 6th harvests caused 1 harvest from the control plot (without using S8) for 1000 Kgs/Hectare and 2 harvests from experiment plot (treated with S8) for 5,280 Kgs/Hectare and this indicates an increase in the harvest with a significant difference of 528%.

3.1.1 First Harvest

Harvest date in experiment plot: S8: 23 May = 4800 Kgs/Hectare.

Harvest date in the control plot: 12 Jun = 3650 Kgs/Hectare.

Harvesting in the experiment plot was done 20 days earlier, the average temperature was recorded at 17.8 °C.

4800 − 3650 = 1150 Kgs/Hectare; Harvest increase = 31.5%.

3.1.2 Second Harvest

Harvest date in experiment plot: S8: 31 Jun = 4880 Kgs/Hectare.

Harvest date in the control plot: 10 Jul = 2820 Kgs/Hectare.

Harvesting in the experiment plot was done 10 days earlier, the average temperature was recorded at 27.3 °C.

4880 − 2820 = 2060 Kgs/Hectare; Harvest increase = 73%.

The average increase in temperature from 23.9 degrees to 27.5 degrees resulted in a yield increase from 31.5% to 73%, which indicates the effect of combined nutrition on increasing chlorophyll density and increasing stem and leaf growth.

3.1.3 Third Harvest

Harvest date in experiment plot: S8: 30 Jul = 5160 Kgs/Hectare.

Harvest date in the control plot: 14 Aug = 3230 Kgs/Hectare.

Harvesting in the experiment plot was done 15 days earlier, the average temperature was recorded at 27.5 °C.

5160 − 3230 = 1930 Kgs/Hectare; Harvest increase = 59.75%.

After the harvest of the second stage in the control plot on 10 Jun 2022, we faced the start of hot days in 3rd stage. In this period, the number of days reported with a temperature higher than 35 °C was 15 days. Due to harvest in the second stage and the lack of enough branches and leaves in the plant, we observed the minimum temperature tension in the control plot. This has led to the restoration of the plant and increased yield compared to the second period. The yield increase in the third harvest compared to the second harvest in the control plot is 3230 − 2820 = 410 Kgs/Hectare, *i.e.*, 14.5%.

3.1.4 Fourth Harvest

Harvest date in experiment plot: S8: 3 Sep = 4210 Kgs/Hectare.

Harvest date in the control plot: 17 Sep = 2020 Kgs/Hectare.

Harvesting in the experiment plot was done 14 days earlier, the average temperature was recorded at 27.3 °C.

4210 − 2020 = 2190 Kgs/Hectare; Harvest increase = 108.4%.The number of days with temperature above 35 °C has been recorded as 12 days. Due to the decrease in the number of hot days, we are still witnessing tension in the Control plot. The significant difference of 108.4% indicates the proper performance of combined feeding by S8.

3.1.5 Total Yield in Water Stages of Growth

The plant is under heat tension during this period. In the first four stages, both control and experiment plots were irrigated. The total harvested fresh fodder in 4 harvests in the Control plot is 11720 Kgs/Hectare and the total harvest in the experiment plot is 19050 Kgs/Hectare.

Productivity increases in experiment plot: 19050 − 11720 = 7330 Kgs/Hectare = 62.5%.

3.1.6 Fifth and Sixth Harvests

In this period, irrigation has not been done due to water shortage and the crop harvest was studied underwater tension. The harvest dates in the experimental plot were 13 October and 22 November with a total amount of 5280 Kgs/Hectare and the harvest dates in the control plot were 22 November for 1000 Kgs/Hectare.

Yield increase: 5280 − 1000 = 4280 Kgs/Hectare = 428%.

3.1.7 Total Yield in Six Harvest Periods

The yield of the experiment plot treated with S8 was recorded to be 24330 Kgs/Hectare and the yield of the Control plot was recorded to be 12720 Kgs/Hectare. Yield increase: 24330 – 12720 = 11610 Kgs/Hectare = 91.27%.

4. Conclusion

Nutrient solution enriched by S8 and Matrix Nutrition technique was applied on the experiment plot. The growth stages of Alfalfa after each harvest. Due to the high temperature in the hot months of the year and thermal tension and shortage of water and water shortage tension at the end of the agricultural season, a total of six harvests from the experiment Plot and 5 harvest from the control Plot, was done within one cultivation period.

The total harvest was equal to 24330 Kgs/Hectare in the experiment plot and 12720 Kgs/Hectare in the control plot. The difference in fresh fodder harvest was recorded as 11610 Kgs/Hectare which represents a yield increase of 91.27%. The total harvest of dry fodder in the experiment plot was equal to 7007 Kgs/Hectare and 2908 Kgs/Hectare in the control plot.

The difference in dry fodder harvest was recorded to be 4099 Kgs/Hectare which represents a yield, increase of 240.95%. The difference in the percentage of dry material in the fodder was recorded as 28.88% in the experiment plot and 22.89 in the control plot which caused an increase of dry material in the experiment plot at 5.99%. Based on the analysis, the average protein content of fodder was measured as 19.4% in Experiment Plot and 17.81% in the control plot. Also, the application of S8 caused the plant to be more tolerant to water shortage tension and thermal tension of above 35 °C and resulted in a yield increase of 173% in the highest thermal tension in hot months of the year (Jun to Aug) and yield increase of 258% in water tension at the end of agriculture season.

Comparison of temperature stress in harvesting numbers 2, 3, and 4 in the control plot:

After the first harvesting of the control plot in mid of June, Temperature rises from 35 to 40 degrees Centigrade and the plant is placed in temperature stress above 35 degrees. To this period, the harvest reduction is -22.7%.

2820 − 3650 = -830 kg = -22.7%.

After the second harvesting of the control plot in mid of Jul, temperatures of 38-40 degrees centigrade have been reported for more than 15 days. On the other hand, with the second harvest in the middle of Jul and Due to the lack

of branches and leaves, the lowest temperature stress is entered into the plants and the plants have the lowest transpiration, the plants have the opportunity to regenerate, and the third harvest increased by +14.5% compared to the second harvest.

After the third harvesting of the control plot in mid of September, the temperature stabilized at 38 degrees Centigrade, Due to the lack of branches and leaves, the lowest temperature stress is entered into the plants, and it seems that the increase in harvest is observed as in the third harvest period. However, due to the high & constant temperature stress and damages caused by the previous Jul stress, the harvest reduction was recorded to be -22.7%.

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