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# Effect of thermal requirements on chemical content of sugar beet and it's reflecting on yield in Upper Egypt

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**A B S T R A C T**

A field experiment was carried out to calculate the effect of thermal requirements and its relation to the yield and chemical content of sugar beet during two growing seasons in Upper Egypt. The temperature effects on sodium, potassium, and alpha - amino nitrogen contents. There was a high correlation between growing degree days (GDD) of three harvesting dates and three sugar beet varieties. The results indicated that increasing harvesting date increased roots and sugar yields.




**Graphical Abstract**

## 1. Introduction

Plant development depends on temperature and requires a specific amount of heat to develop from one point in their lifecycle to another, such as from seeding to the harvest stage.[1] Temperature in growth periods later in the growing season after full plant cover also influenced sucrose, Sodium, potassium and alpha - amino nitrogenconcentrations.[2] Sugar beet (Beta vulgaris var. saccharifera, L.) ranks as the most important crop from the sugar crops in Egypt, producing about 57% of sugar production in 2016/2017 season. In Egypt, it could be cultivated widely in newly, without competition with other winter crops due to its tolerance to salinity and ability to produce high sugar yield under saline conditions and limited water requirements in comparison to the other traditional winter crops.[3] The sugar industry depends on sugar cane and sugar beet crops to produce sugar, where the latter contributes more than 33% of world production of sugar, and 57.7 % locally in Egypt with a total production of 1.32 million tons of sugar.[4] Calculating the accumulation of temperatures has many uses. Although GDD cannot be predicted, climate data records can be used to assess growth potential and provide a measure of

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the possibility of success for particular crop.[5] impact of climatic factors and the interactions between planting and harvesting dates on different genotypes of sugar beet. The most important factors in the study affecting sugar yield were growing degree days, insolation and number of days from planting to harvest.[6]

The harvesting age is one of the main factors which directly affect maturity and consequently root yield and juice quality of sugar beet. Sugar beet varieties differ inherently in their maturity ages, which extend from 150 to 240 days, through which changes in quality, yield and its components occur until they reach their maximum values.[7-9]Sugar beet varieties is considered one of the essential wings of sugar production, in terms of its root yield and quality characteristics. In this context they found differences among beet varieties.[1,10,11,]

The main objectives of this study were to calculate thermal requirements and their impact on the yield of sugar beet for three varieties and harvesting dates in Upper Egypt.

## 2. Results and Discussion

### *2.1 Growing Degree Days (GDD):*

Results as recorded in **Tables 1** and **2** show the GDD calculated for sugar beet varieties during 2018/2019 and 2019/20 seasons under different harvest dates treatments.

Results in **Tables 1** and **2** show the GDD during the different growth stages of the first harvest date treatment (growing season length “GSL” = 180 days). The results indicated that the GDD of the three varieties $V_1$, $V_2$ and $V_3$ respectively during the establishment stage (germination) was 198,198 and 297 and number of days of the stage 13, 13 and 20 days in the first season 306, 349 and 349 and number of days of the stage17, 20 and 20 days in the second season. However, the GDD during vegetative growth stage for the respective three varieties registered 786, 811 and 657 and number of days of the stage 91, 94 and 80days in the first season 654, 554 and 611and number of days of the stage 79, 68 and 76 days in the second season. In addition, the GDD of harvest stage recorded values of 1120, 1095 and 1150 and number of days of the stage 76, 73 and 80 days in the first season, 1254, 1311 and 1254 and number of days of the stage 84, 92 and 84 days in the second season.

It is worth mentioning that the GDD values of the establishment and vegetative growth stages of the second harvest date treatment (GSL = 195 days) and the third harvest date treatment (GSL = 210 days) were equal to the GDD of the first harvest date treatment. The difference in the GDD values occurred in the last growth stage (harvest stage) due to the increase in the length of the growing season 15 days and 30 days for the second and third harvest dates treatments, respectively compared to the first harvest date treatment.

The GDD values for the harvest stage of the three varieties respectively were 1456, 1431 and 1486 and number of days of the stage 91, 88 and 95 days in the first season; 1610, 1667 and 1610 and number of days of the stage 99, 107and 99 days in the second season in the second harvest date treatment. While, these values with the third harvest date treatment reached 1856, 1831 and 1886and number of days of the stage 106, 103 and 110 days in the first season; 1926, 1983 and 1926 and number of days of the stage 114, 122 and 114 days in the second season. found that that plant development depends on temperature and requires a specific amount of heat to develop from one point in their lifecycle to another, heat units are involved in several physiological processes like specific amount of heat units required for the plant at each stage from its germination to harvest of the crop would vary and the important processes are growth and development, growth parameters, metabolism, biomass, physiological maturity and yield.[3,12]

**Table 1.** Cumulative growing degrees days during the different growth stages of sugar beet varieties under the conditions of the harvest dates in the of 2018/2019 season.

| Treatments | 180 days | | | | | | 195 days | | | | | | 210 days | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RAVEL | | SV1841 | | SA1686 | | RAVEL | | SV1841 | | SA1686 | | RAVEL | | SV1841 | | SA1686 | |
| Stage | days | GDD | days | GDD | Days | GDD | Days | GDD | days | GDD | days | GDD | Days | GDD | days | GDD | days | GDD |
| Est. | 13 | 198 | 13 | 198 | 20 | 297 | 13 | 198 | 13 | 198 | 20 | 297 | 13 | 198 | 13 | 198 | 20 | 297 |
| Veg. | 91 | 786 | 94 | 811 | 80 | 657 | 91 | 786 | 94 | 811 | 80 | 657 | 91 | 786 | 94 | 811 | 80 | 657 |
| Ha. | 76 | 1120 | 73 | 1095 | 80 | 1150 | 91 | 1456 | 88 | 1431 | 95 | 1486 | 106 | 1856 | 103 | 1831 | 110 | 1886 |
| Total | 180 | 2104 | 180 | 2104 | 180 | 2104 | 195 | 2440 | 195 | 2440 | 195 | 2440 | 210 | 2840 | 210 | 2840 | 210 | 2840 |

**Table 2.** Cumulative growing degrees days during the different growth stages of sugar beet varieties under the conditions of the harvest dates in the of 2019/2020 season.

| Treatment s | 180 days | | | | | | 195 days | | | | | | 210 days | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RAVEL | | SV1841 | | SA1686 | | RAVEL | | SV1841 | | SA1686 | | RAVEL | | SV1841 | | SA1686 | |
| Stage | day | GD | day | GD | day | GD | Day | GD | day | GD | day | GD | day | GD | day | GD | day | GD |
| Est. | 17 | 306 | 20 | 349 | 20 | 349 | 17 | 306 | 20 | 349 | 20 | 349 | 17 | 306 | 20 | 349 | 20 | 349 |
| Veg. | 79 | 654 | 68 | 554 | 76 | 611 | 79 | 654 | 68 | 554 | 76 | 611 | 79 | 654 | 68 | 554 | 76 | 611 |
| Ha. | 84 | 1254 | 92 | 1311 | 84 | 1254 | 99 | 1610 | 107 | 1667 | 99 | 1610 | 114 | 1926 | 122 | 1983 | 114 | 1926 |
| Total | 180 | 2214 | 180 | 2214 | 180 | 2214 | 195 | 2570 | 195 | 2570 | 195 | 2570 | 210 | 2886 | 210 | 2886 | 210 | 2886 |

*2.2 Growing Degree Day Accumulation (CGDD)*

Data in **Tables 1** and **2** shows the CGDD of sugar beet crop during the 2018/19 and 2019/20. Values of CGDD were 2104, 2440 and 2840 in the first season 2214, 2570 and 2886 in the second season for the three harvest dates treatments and sugar beet varieties respectively. From the previous results it is clear that sugar beet crop needs accumulated growing degree days ranging from 2100 to 2200 if the harvest date is 180 days, 2400-2600 when harvest date equals 195 days, 2800-2900 if harvest is 210 days.

With regard to the impact of intra annual weather variability (fluctuation from year to year) on the GDD needed to move from one stage to another during the sugar beet growth stages, the results showed that the establishment stage was delayed in the second season, resulting in an increase in the GDD values needed for this stage. According to daily temperature data recorded for the study area, the maximum and minimum temperatures increased by 2-5 °C on more days in the second season, resulting in significantly delayed establishment. It was reported that plant development depends on temperature and requires a specific amount of heat to develop from one point in their lifecycle to another, such as from seeding to the harvest stage. Temperature is a key factor for the timing of biological processes, and hence the growth and development of plants.[12]

*2.3Yield and its components*

*2.3.1 Effect of harvesting dates on Roots yield (t/fed.) and Sugar yield (t/fed.).*

The result of harvesting dates for Roots yield (t/fed.) and Sugar yield (t/fed.) are presented in **Table 3** significantly. The results clearly indicated that the longest harvesting date gradually creased Sugar yield (t/fed.) and Sugar yield (t/fed.) in both growing seasons. However, the highest Roots yield and Sugar yield (t/fed.) by harvesting date of 210 days (39.17 and 38.27t/fed.) and (6.51 and 6.31 t/fed.) followed by harvesting date of 195 days (35.92 and 34.26t/fed.) and (5.94 and 5.65 t/fed.) While the lowest mean of Roots yield (t/fed.) and Sugar yield (t/fed.) by harvesting date of 180 days in the first and second seasons could be attributed to climatic conditions in particular the effect of temperature on growth, photosynthesis and respiration. The delay at the time of harvest increased root yield and root sugar content due to extending the growth period and cool nights of autumn, which are the best conditions for sugar producing and reserving in sugar beet.[13,14]

*2.3.2 Effect of sugar beet varieties on Roots yield (t/fed.) and Sugar yield (t/fed.).*

**Table 3** shows that the results of sugar beet types for Roots yield (t/fed.) and Sugar yield (t/fed.) were significant, but for sugar yield was insignificant in the first season. The RAVEL variety (38.87and 35.50t/fed.) and (6.25and 5.98%t/fed.) had the highest Roots yield (t/fed.) and Sugar yield (t/fed.), followed by SA1686 (35.68and 34.77t/fed.) and (5.24and 5.56t/fed.), and SV1841 had the lowest Roots yield (t/fed.) and Sugar yield (t/fed.) in both seasons. These results may be due to the genetic differences among varieties in their performance. In this study RAVEL and SV1841 are monogermcvs while SA1686 is multigerm cv. the differences among mono-germ and multi-germ seed type were insignificant.[11, 15]

**Table 3.** Means of Roots yield (t/fed.) and Sugar yield (t/fed.) of sugar beet crop as effected by irrigation water regimes, harvesting dates and varieties for two growing seasons of 2018/2019 and 2019/2020.

| Treatments | Roots yield (t/fed.) | | Sugar yield (t/fed.) | |
|---|---|---|---|---|
| | 2018/2019 | 2019/2020 | 2018/2019 | 2019/2020 |
| Harvesting dates (H) | | | | |
| 180 days | 32.14 | 29.38 | 5.35 | 4.92 |
| 195 days | 35.92 | 34.26 | 5.94 | 5.65 |
| 210 days | 39.17 | 38.27 | 6.51 | 6.31 |
| L.S.D. (0.05) | *2.43* | *0.91* | *NS* | *0.36* |
| Varieties (V) | | | | |
| RAVEL | 38.87 | 35.50 | 6.25 | 5.98 |
| SV1841 | 32.68 | 31.64 | 5.31 | 5.33 |
| SA1686 | 35.68 | 34.77 | 5.24 | 5.56 |
| L.S.D. (0.05) | 2.14 | 1.20 | NS | 0.45 |
| Interactions | | | | |
| *HV* | *NS* | *NS* | *NS* | * |

* = significant at $F_{.05}$ and N.S = not significant

*2.3.3 Effects of the interactions on Sugar yield (t/fed.).*

Regarding in **Table 4** the interactions effects between the studied factors, on sugar yield (t/fed.) interactions effects between harvesting ages and sugar beet varieties on sugar yield was significant in 2nd season only, it is clear that the effect of interaction between harvesting ages and sugar beet varieties the highest values of roots yield (43.46 and 39.86) were obtained from 210 days with RAVEL variety followed by SA1686in the 1st and 2nd seasons.

**Table 4.** Sugar yield (t/fed.) as affected by the interaction between Harvesting dates and varieties in first season.

| Harvesting dates | Variety | Sugar yield (t/fed.) | |
|---|---|---|---|
| | | 2018/19 | 2019/20 |
| 180 days | RAVEL | 34.43 | 30.91 |
| | SV1841 | 29.11 | 26.56 |
| | SA1686 | 32.89 | 30.66 |
| 195 days | RAVEL | 38.72 | 35.73 |
| | SV1841 | 32.67 | 32.81 |
| | SA1686 | 36.38 | 34.24 |
| 210 days | RAVEL | 43.46 | 39.86 |
| | SV1841 | 36.27 | 35.56 |
| | SA1686 | 37.79 | 39.40 |
| *L.S.D.*$_{0.05}$ | | *1.83* | *0.78* |

In general, as temperature and Growing degree days (GDD) increased sucrose content decreased and increased Sodium present, potassium present and alpha - amino nitrogen present.

## 3. Conclusion

Changes in seasonal climatic temperatures were linked to sugar beet sucrose content, Sodium, potassium and alpha - amino nitrogen contents. The more sucrose the less sodium, potassium and alpha - amino nitrogen contents. The stages included in this work are: assess the suitability of a region for production of a particular crop based on their treatment, determine the growth-stages of crops, predict best timing of fertilizer or herbicide and plant growth regulator application based on the growth stage, estimate the heat stress on crops, and predict the maturity (physiological) and harvest dates. The results showed that the first season of the roots yield (t/fed.) and sugar yield is better than the second season, the reason for this could be that sugar beet was received at temperatures that were higher than in the first season, high temperature induces inhibition of photosynthesis which leads to reduced yield.

## 4. Experimental

### *4.1 Materials and methods*

A field experiment was carried out at Shandaweel Agricultural Research Station at Sohag, Egypt (latitude of 26˚ 26' N, longitude of 31º 68' E and altitude of 70 m) in two consecutive seasons of 2018/2019, 2019/2020 to calculating thermal requirements and their effect on the yield of sugar beet for three varieties and harvesting dates in Upper Egypt conditions. The experiment was laid out in a Randomized Complete Block Design keeping the combination of three harvesting dates; $H_1$ = 180, $H_2$ = 195 and $H_3$ =210 days from sowing as the main plots and were comprised three sugar beet varieties namely: $V_1$ = RAVEL (mono variety), $V_2$ = SV1841 (mono variety) and $V_3$ = SA1686 (multi-germ). The plot area was 10.5 $m^2$ (3 x 3.5 m). Sugar beet seeds of the three varieties were sown on 8 and 7 November in the 1st and 2nd seasons, respectively. From 3 to 4 seeds were used in each hill 20 cm apart between two consecutive hills. All treatments were fertilized with P-fertilizer in the form of mono-calcium (MCP) phosphate (15.5% $P_2O_5$) at the rate 67.5 kg $P_2O_5$/ha added to the soil during land preparation. Nitrogen fertilizer was applied in the form of ammonium nitrate (33.5% N) at the rate of 225 kg N/ha divided into two equal doses (before the first and second irrigation). Potassium fertilizer in the form of potassium sulfate 48% $K_2O$ was applied at the rate of 54 $K_2O$/ha and added during the second irrigation. The other farming practices required for sugar beet growth were carried out according to the common practices followed at Shandaweel station. Traditional furrow irrigation method for irrigation was used during both growing seasons. P-fertilizer in the form of mono-calcium (MCP) phosphate (15.5% P2O5), nitrogen fertilizer in the form of ammonium nitrate (33.5% N), and potassium fertilizer in the form of potassium sulfate 48% K2O was purchased from agricultural research center, Egypt.

Recorded data:

*Calculation of growing degree days (GDD):*

Plant growth and productivity are influenced by the atmospheric factors of the plant's growing environment. The plant needs a certain amount of heat to move from one stage to another in order to complete its growth. The smallest temperature is called zero growth or basic temperature or threshold temperature ($T_{base}$), while the maximum temperature is called Upper threshold temperature (Tupper). The calculating GDD was done by the average daily temperature [maximum temperature ($T_{max}$.) plus minimum temperature ($T_{min}$.) divided by 2] minus $T_{base}$.[16] 5°C was relied upon to represent $T_{base}$of sugar beet crop. The calculation was done according to the following equation:

$$\text{Daily GDD} = \frac{(Tamx + Tmin)}{2} - Tbase$$

*GSL= Growing season length

Plant samples were then sent to the laboratory of quality analyses at laboratory of Abu Kurgas to determine the following quality characteristics:
At each of the studied harvest ages, a random sample of five guarded roots of each plot was taken to determine the following traits:

1. Root yield (t /fed). It was calculated based on root yield/ plot.
2. Sugar yield (t/fed.) was calculated as follows:

$$Sugaryield\left(\frac{t}{fad.}\right) = Rootyield\left(\frac{t}{fad.}\right) \times ES\%$$

**Table 5.** Average values of meteorological data recorded at Shandaweel Agricultural Research Station in 2018/2019 and 2019/2020 growing seasons.

| Months | 2018/2019 | | | | | 2019/2021 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Temperature (ºC) Max. | Temperature (ºC) Min. | RH (%) | WSm/sec | SR (%) | Temperature (ºC) Max. | Temperature (ºC) Min. | RH (%) | WSm/sec | SR (%) |
| Nov. | 26.6 | 13.0 | 54 | 2.3 | 13 | 28.8 | 14.5 | 59 | 2.3 | 17 |
| Dec. | 20.3 | 7.1 | 65 | 2.5 | 15 | 21.7 | 7.9 | 58 | 2.4 | 15 |
| Jan. | 18.8 | 5.0 | 60 | 2.1 | 15 | 18.3 | 4.3 | 58 | 2.5 | 15 |
| Feb. | 21.5 | 7.1 | 48 | 2.6 | 18 | 21.4 | 6.6 | 52 | 2.6 | 19 |
| Mar. | 25.1 | 9.1 | 35 | 2.9 | 23 | 27.2 | 10.6 | 45 | 3.1 | 22 |
| Apr. | 30.1 | 13.8 | 34 | 3.2 | 24 | 30.1 | 14.0 | 37 | 3.4 | 25 |
| May | 38.4 | 20.8 | 30 | 3.0 | 27 | 36.0 | 19.8 | 36 | 3.4 | 27 |

WS= wind speed m/sec; SR = solar radiation, MJ/m$^2$/day, RH =relative humidity in % ETo= evapotranspiration, mm

*Statistical analysis*

The obtained data were subjected to statistical analysis of variance using the MSTAT_C computer program. The means were compared for significant differences using the L.S.D. at p=0.05.[17] It is very interesting to clarify that this work confirms the previous data that elucidate the importance of scientific research in nature.[18-59]

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