Dry Matter Production and Partitioning Pattern in Sugar Beet

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***Abstract*—**The investigation was conducted to study dry matter production and partitioning of assimilates in sugar beet. This study was undertaken during 2010 at the farm of Khorasan Agric. Res. Center located in southern west of Mashhad, Iran. Ten different genotypes of sugar beet i.e. 461, 419, 7617, 8090, 436, 428, 231, 474, 7233-P12 and Kahriz were compard using a Randomized Complete Block design with 4 replications. Results showed a slow increment in dry matter production in early season followed by a rapid and almost constant phase and finally another period of slow growth. The genotypes under study were divided into two groups (by Cluster analysis) namely, Low yielded and High yielded genotypes based on dry matter production. Foliage dry matter was higher than roots during 50 days after emergence but it changed in favour of roots later on so that the growth of roots dominated foliage parts of crop. This pattern were continued for about100 days after emergence. Since then almost the whole produced dry matter were diverted to roots by the end of season. Root/Shoot ratio were linearly increased during the growth season, and it was higher in high yielded genotypes. Sugar yield were increased with a linear trend in different genotypes about 100 days after emergence till harvest time. Significant difference between various genotypes from Harvest Index point of view were not recorded.

***Keywords*—**Genotype, Harvest Index, Partitioning of Assimilates, Sugar beet .

I. Introduction

The sugar yield in sugar beet is a function of the total dry matter accumulation and the ratio of the allocation of photosynthetic material to root growth and sugar storage in it. There is relatively little information about the mechanism for distributing dry matter between different parts of the plant. According to researchers, several factors such as length of day and genotypes are effective on dry matter allocation patterns (18). The ratio of the distribution of material to the roots and the organs during the growing season leads to different growth stages in sugar beet. Several researchers have identified three distinct stages of vegetative growth for sugar beet as follows (14,15). The first stage is that leaf growth is dominant. The second stage is mainly focused on root growth, and the third stage, during which sugar is stored in the root. Milford (1973) has identified two stages for the growth of sugar beet. The primary stage consists mainly of leaf growth and the subsequent stage in which root growth predominates. According to this theory, there are no separate stages for root growth and sugar storage. In the first two weeks of sugar beet growth there is a slight increase in dry matter accumulation. Initially, leaves form the main component of the plant. After that, the rate of accumulation of dry matter in all parts of the plant is faster. The leaf dry matter is almost linearly increased by the tenth week. Root growth rate increases slowly until the 6th week, and then the accumulation of dry matter in the root is greater than the sum of leaves and petioles. This process continues until the root weight is more than the weight of the shoots (1,12). werker et al. (1995) found that the growth trend is sigmoid or S-shaped, so that, following the rapid increase in dry weight, the rate of accumulation of dry weight decreases. Milford et al. (1988) stated that in different experiments there is a significant difference in the ratio of dry matter transferred to the root at the beginning of the growth season. This suggests the absence of a completely definite linear trend for the relationship between root and total dry matter at this stage. However, in the next stages of growth, the major part of the dry matter production is allocated to the root. Scott and Jaggard (2000) found that over the past years, with improvements in breeding, Sugar beet harvest index has increased from 48% to 55%. The aim of this research was to study the pattern of production and allocation of photosynthetic material in sugar beet.

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II. Materials and Methods

This experiment was conducted in 2010 at the Agricultural Research Center of Khorasan, southeast of Mashhad, Iran. The latitude of the experiment was 36°12' N and its longitude is 59° 40'E and its elevation is 985 meters above sea level . After land preparation and fertilization, seeding was done by seeding machine on May 26th. Regular irrigation was carried out every 8 to 10 days, and at four to six leaves stage, seedlings were thinned 20 cm apart. During this experiment, 10 genotypes of sugar beet including 461, 419, 7617, 8090, 436, 428, 231, 474, 7233-p12 and Kahriz were compared in a randomized complete block design with four replications. Each plot consisted of 8 rows with a length of 12 meters, spaced 50 cm from each other. The sampling began three weeks after the emergence and continued every two weeks at one square meter.

In each sampling, fresh weight and then dried weight were recorded separately. To measure the leaf area, the measuring device (ΔT model) was used. After the fifth sampling, a pulp sample was prepared to evaluate the quality of the roots. The final harvest was from two rows of 5 meters in length, late in November. The root samples were analyzed by betalyzer and

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the percentage of sugar by polarimetric method and harvest index were calculated from the following formula (Scott and Jaggard, 2000):

Harvest index = (sugar yield / total dry matter) × 100

For better comparison, the genotypes were clustered by cluster analysis. Data were analyzed by SPSS, MSTATC, and Excel software.

III. Results

The genotypes were divided into two groups of "low yielded" and "high yielded" in terms of total dry matter production. The first group consisted of 461, 8090, and 428 genotypes with the least yield, and genotypes 419, 7617, 436, 231, 474, 7233-p12 and Kahriz formed the high yielded group (Fig. 1). The two groups had a significant difference in terms of root dry matter and total dry matter. The difference in mean dry matter of the two groups was 256 g/m2 (Table 1).

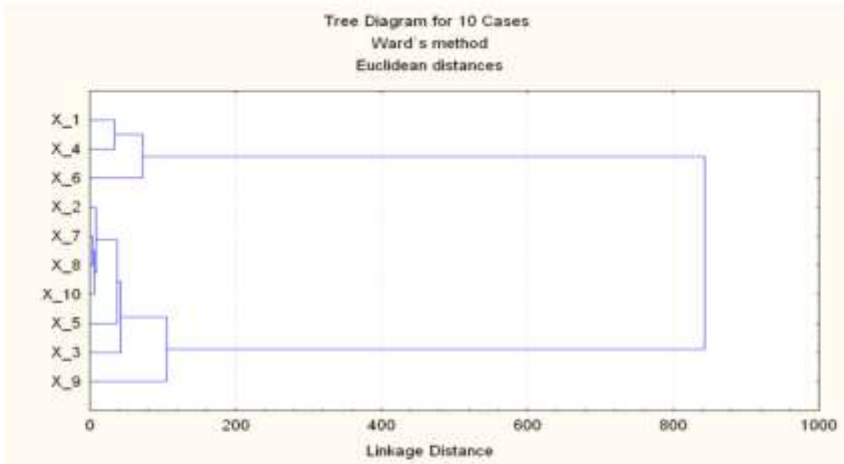

Fig. 1. Sugar Beet Genotypes Grouping Based on Cluster Analysis

TABLE1. MEAN OF SOME TRAITS IN HIGH-YIELDED AND LOW-YIELDED SUGAR BEET GENOTYPES

Genotypes groups	Total Dry Weight (g/m^2)	Root Dry Weight (g/m^2)	Shoot Dry Weight (g/m^2)	Sugar Yield (g/m^2)	Harvest Index %	Maximum LAI
Low-Yielded	1836 ^{a}	1560 ^{a}	276 ^{a}	1123 ^{a}	61.27 ^{a}	3.41 ^{a}
High-Yielded	2092 ^{b}	1830 ^{b}	262 ^{a}	1310 ^{b}	62.61 ^{a}	3.02 ^{a}

Means within each column and year followed by the same letters are not significantly different (Duncan 5%)

As shown in Fig. 2, unlike to the shoot dry weight, the trend of changes of the root and total dry weight was sigmoid. The trend of changes in the distribution of dry matter between root and shoot showed that in early growing season, photosynthetic materials were mainly sent to the shoot (Fig. 3).

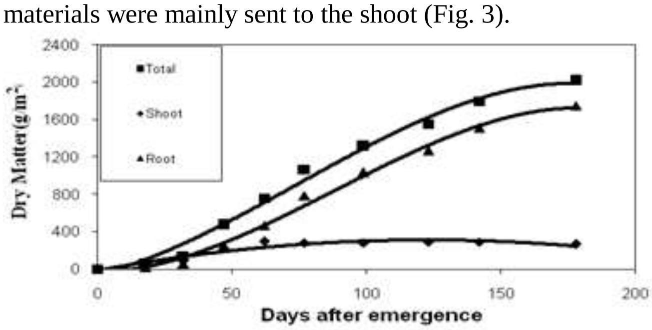

Fig. 2 Changes in root, shoot and total dry matter of sugar beet during the growing season

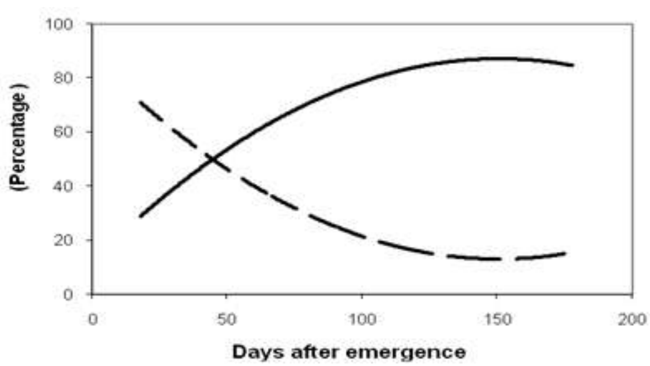

Fig 3. Percentage of root and shoot dry matter relative to Total dry matter during the growing season

After about 50 days of emergence, root growth has increased over the growth of the shoot. This continued until late August (about 100 days after emergence), after which almost all of the dry matter produced was fed to the root. The root dry weight at this stage was about 80% of the total dry weight of the plant, and at harvest time this ratio was 90%. In terms of average final dry weight, a significant difference was found between low yielded and high yielded genotypes, but the difference between these two groups was statistically negligible in terms of shoot dry matter (Table 1). The trend for the leaf area index is shown in Fig. 4.

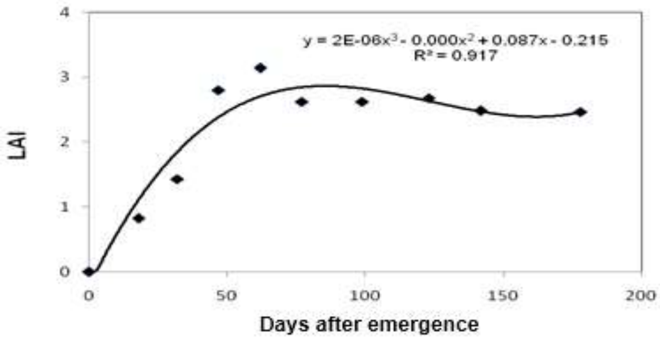

Fig. 4. Changes in Leaf Area Index during the growing season

Differences between low yielded and high yielded genotypes were significant in terms of root to shoot dry weight ratio (Table 1). This ratio increased linearly to time by up to 100 days after emergence. This process continued until the end of the season. This ratio was about 0.6 in the first month and reached more than 1 in the first week of August (75 days after emergence) and ultimately fluctuated between 5.49 to 9.28 at the time of harvest (Fig. 5).

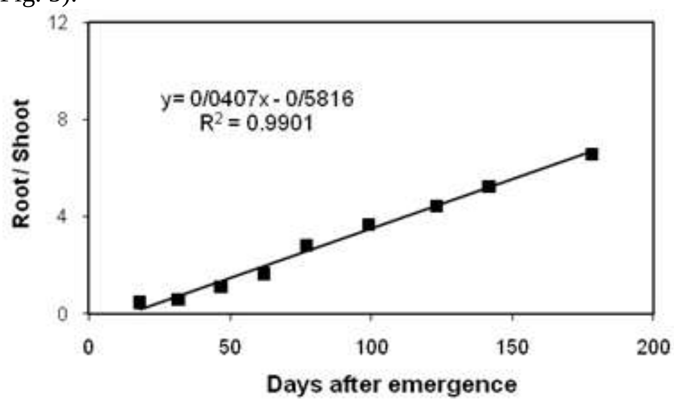

Fig. 5 Sugar Beet root to shoot dry matter ratio during the growing season

The trend of sugar yield changes during sampling (from about 100 days after planting) is shown in Figure 6.

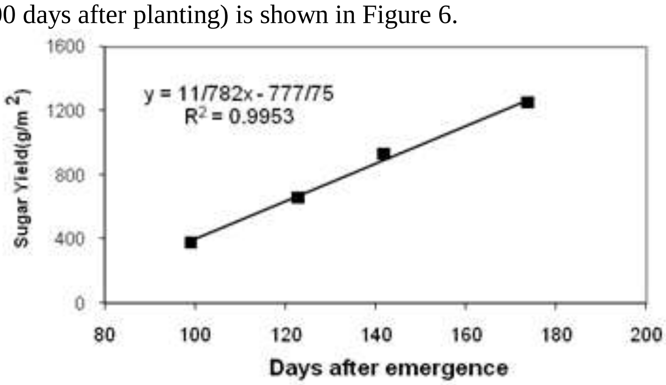

Fig. 6 Change in Sugar Yield of sugar beet genotypes during the growing season

In terms of sugar yield, low yielded and high yielded genotypes were significantly different (Table 1). The results showed that, as the dry matter increased, the sugar yield also increased (Fig. 7). The harvest index varied between 59.09% and 68.03%. According to this index, the difference between genotypes was not significant (Table 1).

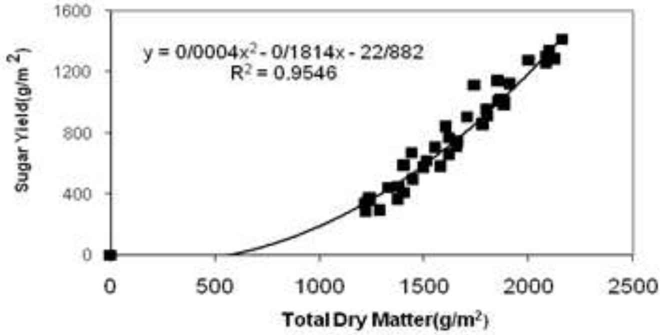

Fig. 7 Change in Sugar Yield relative to total dry matter during the growing season

IV Discussion

As shown in Fig. 2, in the early stages of growth, the accumulation of dry weight is slow because of the distance between plants, the slow growth of small leaves and consequently, the limitation of light absorption (8). After this stage, with the completion of leaf cover, there is a direct relation between the production of dry matter and the amount of light received (3,9). The results of a 13-years experiment at the Broms Barn Research Institute of England indicate that the time to reach the maximum leaf area index is the main factor causing different yields in different years (11).

The results of this study showed that from mid July (50 days after emergence), root growth was dominant in shoot growth and after this stage there was a sudden increase (Fig. 2). Terry (1968) stated that growth of the root slowly increases until about six weeks after emergence, and after that, the accumulation of dry matter in the root increases from the sum of the leaves and the petiole, thus developing separate stages for growth Leaf and root growth. Green et al. (1986) stated that the transition from one stage to another may be due to the shortening of the day. On this basis, it is expected that the rapid root growth takes place in a short time period or at a certain stage of the plant growth period. However, some other reports indicate that, as plant growth, a gradual phase change occurs in the allocation of dry matter to the root, and no sudden transition occurs at a definite stage (8,16).

It seems that the discrepancy regarding the change in the sudden phase of the dry matter allocation, according to what happened in this study, is related to the growth of the shoots. So that in the case where the growth of the shoot is significantly reduced for any reason, there is a sudden phase change. And in cases where the shoots continues to grow due to the lack of restrictive conditions, it is not detectable phase change. In the conditions of this experiment, relatively high temperatures and subsequent drought stress can be a factor in reducing the growth of the shoots and changing the phase in the allocation of materials to the root. With regard to the factors affecting the predominance of root growth, we can point to Milford et al. report (1988). According to this, changes in temperature and nitrogen content can explain differences in the time of change in dominance, as well as the proportion of total dry matter that is subsequently allocated to the root. Terry (1968) stated that at higher and lower temperatures than the optimum temperature of plant growth (24 ° C), the root grows more rapidly than the shoots, and this is probably due to the availability of more materials for root growth, resulting in the slow growth of shoots.

As shown in Figure 7, sugar yield increases with increasing total dry matter. This result is consistent with the results of other experiments (6,19). Terry (1968) reported that sugar yield has a close correlation with root dry weight, and this relationship is independent of temperature and radiation. He also stated that the uniform relationship between root sugar content as well as root dry weight, to the total dry weight of the plant indicates that root growth and sugar storage are controlled by a genotype-dependent mechanism.

It seems that the difference in root to shoot ratio can be a factor in the difference in sugar yield of genotypes, because the mean of this ratio for the high- yielded group was 1.34% higher than the mean for the low-yielded group (Table 1). Loach (1970) stated that cultivars that have a higher root-shoot ratio at the end of the growing season absorb photosynthetic materials more quickly. It is assumed that plants that absorb more photosynthetic material at a faster rate also have a larger root for sugar storage.

The average harvest index in the experiment was more than 60%, with a significant difference with the values for the new cultivars in other countries (55%). The relative increase in the harvest index, was due to the lack of consideration of fiber roots and also the fallen leaves during the growing season. Considering leaf losses, which is about 10% of the total dry weight of the plant (7), the harvest index will be closer to the numbers given for other countries.

The absence of a significant difference between harvest index of different genotypes (Table 1) indicates that the determinant factor of sugar yield in this experiment is the total dry matter.(Because Sugar yield = Harvest index × Total dry matter). These results are contradictory with the results reported by Scott and Jaggard 2000. This researchers, by comparing old and new cultivars, stated that in spite of receiving almost identical light and producing the same biomass (23.4 t / ha), the cultivars had a difference of 1.9 t / ha in terms of sugar yield. The higher yield of sugar in the new cultivar was due to the higher allocation of dry matter to the root after July and the higher harvest index (56.4% in comparison with 49.5% for the older variety).

V Conclusion and Recommendations

Considering the important role of root and total dry matter in determination of sugar yield and the lack of significant effect of harvest index, it is expected that increasing root and total dry matter through crop breeding and farm management will increase sugar yield.

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