Archives of Agriculture Sciences Journal
Print ISSN: 2535-1680
Online ISSN: 2535-1699

ARCHIVES OF AGRICULTURE SCIENCES JOURNAL

Volume 5, Issue 2, 2022, Pages 96–110

Available online at www.agricuta.edu.eg

DOI: https://dx.doi.org/10.21608/aasj.2022.248231

Comparative botanical studies of some cultivated groups of *Beta vulgaris* L. (Chenopodiaceae)

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Abstract

The present study carried out in the experimental farm of Agricultural Botany Department, Faculty of Agriculture, Al-Azhar University (Assiut Branch), Assiut, Egypt, using two pots and field experiments during the two winter seasons (2019/2020 and 2020/2021). to study and compare the botanical (Morphological characteristics, physiological characteristics, anatomical characteristics, yield and quality characteristics) and taxonomic characteristics of the *Beta vulgaris L.* (four groups of beets: sugar beet two cultivars, fodder beet two cultivars, garden beet one cultivar, and leaf beet one cultivar) in the family Chenopodiaceae. The obtained results indicated that sugar beet given the highest values in root diameter, fresh and dry weight of the roots and leaves, on the other hand, fodder beet recorded the highest values in root length and lowest values in leaf area, fresh and dry weight of leaves. While garden beet recorded the highest values for the number of leaves and the lowest values for root length. The leaf beet given the lowest values for root diameter, fresh and dry weight of roots, and the number of leaves. Also, the results indicated that leaf beet scored the highest values in leaf concentrations of chlorophyll a, b, and total chlorophyll followed by garden beet, while fodder beet recorded the lowest values of chlorophyll a, b, and total chlorophyll. On the other hand, sugar beet cultivars are given the highest values in the leaves content of nitrogen and potassium, and the lowest values in the leaves content of phosphorous. While garden beet is given the highest values for phosphorous followed by leaf beet. Data recorded that sugar beet given the highest values in root diameter, parenchyma layer thickness, number and thickness of growth rings, length of xylem arm, midrib thickness, vascular cylinder thickness, vascular bundles thickness in leaves, lowest values for vascular cylinder thickness in the root, mesophyll thickness in leaves. At the same time, fodder beet recorded the highest values for cortex thickness and diameter of xylem big vessels, the lowest values for midrib thickness in leaves vascular cylinder thickness in leaves, and the stomatal density in the leaves. The garden beet had the highest values for vascular cylinder thickness in the root, the stomatal density in the leaves, and the lowest values for root diameter, parenchyma layer thickness growth rings thickness. The leaf beet recorded the highest values for mesophyll thickness in leaves, while the lowest values for cortex thickness, length of xylem arm diameter of xylem big vessels. Also, the results indicated that sugar beet recorded the highest values in the content of sucrose percentage, Extractable sugar percentage, quality ratio, and the lowest values in the sodium content in the root, α-amino N. While fodder beet given the highest values in root content of potassium, sodium, and Impurities percentage, and the lowest values in root sucrose content, Extractable sugar percentage, quality percentage. At the same time, the garden beet cultivar recorded the lowest values of potassium and Impurities percentage in roots. The leaf beet given the highest values in root content of α-amino N. These results reinforce the classification of the beet genus into four cultivated groups, namely and clarify the degrees of kinship and the relationship between them as follows, sugar beet group, fodder beet group, garden beet group, and leaf beet group.

Keywords: sugar beet, fodder beet, garden beet, leaf beet, anatomical, yield and quality characteristics.

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1. Introduction

The family Chenopodiaceae is one of the important botanical families. It is one of the most difficult groups of flowering plants in terms of its taxonomy and diagnostics (Sukhorukov *et al.,* 2019). The Chenopodiaceae, commonly known as the goosefoot family, is cosmopolitan, but especially abundant in saline or alkaline habitats (Ghadi *et al.,* 2006; Sukhorukov and Kushunina, 2014). Members of the Chenopodiaceae are widely distributed in the steppe, desert, and saline-alkaline areas in southern Africa, Central Asia, South America, and Oceania, and along the coast of the Mediterranean, Caspian, and Red seas (Culham, 2007; Punsalpaamuu *et al.,* 2012). The family is of some economic importance as it surpasses all others for "greens" or pot-herbs due to the succulent nature of young stems and leaves. And include one source of sugar. The family has considerable forage value because none of the members is poisonous (Iwuozor and Afiomah, 2020; Ninfali and Angelino, 2013). Family Chenopodiaceae belong to the dicotyledonous flowering plants and belong to the order Caryophyllales. It comprises about 100 genera and approximately 1600 species distributed worldwide (Sukhorukov, 2014), and it is a sister group to Amaranthaceae according to molecular investigations (Kadereit *et al.,* 2003). The two families have indeed long been recognized to be closely allied and positioned side by side in almost all classifications (Cronquist, 1981). However, other phylogenetic analyses indicate that although the two families form a monophyletic clade, their relationship to each other is not fully resolved (Kadereit *et al.,* 2003; Müller and Borsc,h 2005). Therefore, we continue to recognize the two families as distinct from one another (Culham, 2007). Many genera belonging to this family are highly respected, such as *Beta, Salsola, Chenopodium, Kochia, Atriplex, Sarcobatus,* and *Eurotium* (TurKi *et al.,* 2008). Genus *Beta* is an economic Plant important. In addition to the cultivated forms of them (*Beta vulgaris subsp. vulgaris*), it also includes wild or weed forms, such as the subspecies *Beta vulgaris ssp. maritime* (Vastarelli *et al.,* 2012). *Beta vulgaris* is a biennial herb, or rarely a perennial, with a height of up to 120 cm (rarely 200 cm) (Shultz, 2003). Sugar beet (*Beta vulgaris L. subsp. vulgaris var. altissima*) is the main crop of *Beta L.* and the most economically valuable crop species in the Dianthus (McGrath *et al.,* 2011). Sugar beets provide about one-third of global sugar consumption and are used as an important source of bioenergy in the form of ethanol (Biancardi *et al.,* 2012; Jung *et al.,* 2015). Fodder beet (*Beta vulgaris L. subsp. vulgaris var. alba*), also called “mangel” or “mangold” or “forage beet”, the plant is used as a valuable source of cattle feed. Beet has high water content and sugar content, which can increase dairy products and is a suitable feed for dairy cows (Hussein and Siam, 2012). Garden beet or Table beet (*Beta vulgaris L. subsp. vulgaris var. conditiva),* the root contains a small amount of fiber, if harvested at the right time, it can be eaten raw or cooked (Biancardi *et al.,* 2020). Several parts of this plant are used in the medicinal system such as antioxidant, anti-depressant, anti-microbial, anti-fungal, anti-inflammatory, diuretic, expectorant, and carminative (Jasmitha *et al.,* 2018), and contains secondary metabolites, called betalains, which are used as natural dyes in the food industry and show anticancer activity (Ninfali and, Angelino, 2013). Leaf beet common name for Swiss chard *(Beta vulgaris L. subsp. vulgaris var. cicla*), It has many common names, such as silverbeet, perpetual spinach, beet spinach, seakale beet, or leaf beet. It is composed of cultivars whose leaves and petioles are used as vegetables. The size and shape of the leaves and the thickness of the midrib and petiole vary. Generally, there are no swollen hypocotyls and/or roots because the thickness of the roots may vary greatly, but they are never fleshy (Klapp, 1967). Like other green leafy vegetables, the leaves of beet are rich in nutrients, making them a popular ingredient in a healthy diet (Conde Nast, 2014). Therefore, we aim from this study to clarify the relationships and differences between the four cultivated groups of the genus Beta and their taxonomic status in the family Chenopodiaceae. And access to the largest number of common taxonomic characteristics of them in a way that emphasizes the clarification of the ties of kinship between them and places them in the correct divisional ranks within the plant kingdom.

2. Materials and methods

Two pots and Field experiments were carried out on the experimental farm of the Agricultural Botany Department, Faculty of Agriculture, Al-Azhar University (Assiut Branch), Assiut, Egypt, during the two winter seasons (2019/2020 and 2020/2021). To study the botanical and taxonomic characteristics of the *Beta vulgaris* L. (four groups of beets: sugar beet two cultivars, fodder beet two cultivars, garden beet one cultivar, and leaf beet one cultivar) in the family Chenopodiaceae. The seeds were sown on 28th October, during the two growing seasons in both pots and field experiments. Pots, 45 cm Ø were filled with the soil from the experimental farm. Then seeds were sowed (2-3 seeds/pot). After the emergence of seedlings were thinned to one plant per pot. The pots were arranged in a randomized complete blocks design (RCBD). The Normal cultural practices as recommended by Agriculture Research Center, Egypt were done, and disease control was carried out whenever it was necessary. Different morphological characteristics and the chemical analysis of plant samples were taken at the reported dates during the experimental period. 3 plants replicated from each treatment were randomly taken for different measurements. The plants were separated into their organs (roots, and leaves) then the freshly weighting was recorded for each. After that, the samples of these organs were dried in the oven at 70 C° for 48 hours till constant weight. The dried samples of different organs were weighted for dry weight estimation. These dry samples were kept for chemical analysis determinations. The data were taken at 50, 80 and 110 days from sowing during two seasons as follows:

2.1 Morphological characteristics

Root length (cm), Root diameter (cm), Root fresh and dry weight (g/plant), Number of leaves, Fresh and dry leaves weight (g/plant), Leaf area (cm^2/plant).

2.2 Physiological characteristics

2.2.1 The photosynthetic pigments

Chlorophyll A and B and total chlorophyll were measured as per the method suggested by Sadasivam and Manickam (1997).

2.2.2 Chemical compounds in leaves

Total nitrogen percentage was determined by using the micro-Kjeldahl method outlined in the A.OA.C. (1995). Total phosphorus percentage was determined by the ascorbic acid method using the colorimetric method described by John (1970). Potassium (%) content was estimated using a flame photometer as described by Person (1976).

2.3 Anatomical characteristics

For preparing sections, the roots, and Leaves specimens were taken after 65 days from seed sowing. Root pieces of 4-5 mm in length were taken 2 cm far from the tip of the main fleshy roots and taken from the fourth Leaf. Samples were killed and fixed for at least 48 hours. In formalin acetic acid alcohol (F.A.A.) solution [5 ml glacial acetic acid, 10 ml formalin, and 85 ml ethyl alcohol 70%]. Samples were washed in 50% ethyl alcohol and dehydrated in a normal butyl alcohol series. The dehydrated specimens were infiltrated and embedded in paraffin wax (45-50 °C m. p.). The embedded specimens were sectioned on a rotary microtome at a thickness of 10 – 12 µm. Sections were mounted on slides and deparaffinised. Staining was accomplished with safranin and light green, cleared in xylol and mounted in Canada balsam (Nassar and El-Sahar, 1998). Slides were examined microscopically and photomicrographed.

2.3.1 Roots characteristics

Ø of root (mm), Parenchyma layer thickness (µm), Cortex thickness (µm), Ø of V. C. (µm), number of growth rings, growth rings thickness (µm), xylem arm length (µm) and Ø of xylem big vessels (µm).

2.3.2 Leaf characteristics

Midrib thickness (µm), mesophyll tissue thickness (µm), Ø of V.C. (µm), V.B. thickness (µm), and xylem arm length (µm).

2.3.3 Stomatal types

Length, and width stomatal wideness, stomatal density in mm^2, the data were taken at 110 days from sowing during the second season.

2.4 Yield and quality

Sugar (%), quality (%), sodium (Na %), potassium (K %), and α amino nitrogen (N%) were determined in Abo Korkas Sugar Factory, El Minya, Egypt of an automatic sugar polarimetric (El-Zayat, 2000) at harvesting date (200 days) from sowing in both seasons. Extractable sugar percentage (ES %) was determined according to Renfield *et al*. (1974) as following:

ES% = pol - [0.343 (K + Na) + 0.094 α-amino N + 0.29]

Where pol = sucrose percentage.

Impurities percentage = [0.343 (K + Na) + 0.094 α-amino N + 0.29]

2.5 Statistical analysis

Analysis of the variance of the data was carried out on the mean values of the tested treatments according to the procedures described by Gomez and Gomez (1984). The least significant difference (L.S.D.) at 5% probability was used for testing the significance of the differences among the mean values of the tested treatments for each character.

3. Results and Discussion

3.1 Morphological characteristics

The results in Table (1) showed significant differences between the studied cultivars for the characteristics of roots and leaves during different ages (50, 80 and 110 days). Fodder beet cultivar showed the highest values in root length and lowest values in leaf area and leaf fresh and dry weight. On the other hand, sugar beet showed the highest values in root diameter, fresh and dry weight of root, leaf, and leaf area. While garden beet showed the highest values in the number of leaves and the lowest values in root length, fresh weight, and leaves in agreement with fodder beet, while leaf beet also gave low values in root length as it gave the lowest values in root diameter, roots fresh and dry weight, and the number of leaves at different ages during the trial period. The concordance was high between the two sugar beet cultivars, followed by the concordance between the two fodder beet cultivars for the concordance of the four groups of the study solution. The fodder beet cultivars and the sugar beet cultivars are distinguished by the highest values in root length, root diameter, root fresh and dry weight, because their roots are conical or spindle-shaped, unlike garden beets, even though their roots are stored, but they are turnip shape and smaller in size, while leaf beets have branched roots. Not stored. This agrees with what was reached by Ninfali and Angelino (2013), El-Emary (2017), and Biancardi et *al.* (2020).

3.2 Physiological characteristics

The results in Table (2) showed significant differences between the studied cultivars in terms of the chemical and physiological characteristics of the leaves. Where leaf beet gave the highest values in leaves concentration of chlorophyll a, b, and total chlorophyll followed by garden beet, while fodder beet gave the lowest values in leaves content of chlorophyll a and b and total chlorophyll. High values of leaf and garden beets are considered an indicator of the early maturity of these cultivars. On the other hand, the two sugar beet cultivars gave the highest values in the leaves content of nitrogen and potassium, and the lowest values in the leaves content of phosphorous. While garden beet gave the highest values for phosphorous content of leaves, followed by leaf beet, and the lowest values for leaves nitrogen content. This makes them a leafy green that is rich in nutrients. The fodder beet gave the lowest values of potassium content of leaves; thus, its leaves are used, in addition to sugar beet leaves, in preparing silage to feed the animal. Nitrogen, phosphorus, and potassium are some of the most important biochemical components of plant organic matter, and hence, estimation of their contents can help monitor the metabolism processes and health of plants. These results are in line with those obtained by El-Nady, (2006) and El-Emary (2017).

Table (1): Morphological characteristics of roots and leaves in some cultivated beet groups at 50, 80 and 110 days from sowing during the 2019/2020 and 2020/2021 seasons.

Varieties	Morphological characteristics at 50 days															
	Root length (cm)		Root diameter (cm)		Root fresh weight (g/ plant)		Root dry weight (g/ plant)		Leaves number (/plant)		Leaves area (cm^2/ plant)		Leaves fresh weight (g/ plant)		Leaves dry weight (g/ plant)	
	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
Fodder beet (1)	48.33a	33.00a	0.77ab	0.45c	3.77c	4.80c	0.75b	0.52bc	8cd	10b	13.18bc	8.87c	16.07d	10.95e	1.60c	1.51c
Fodder beet (2)	42.00b	26.33b	0.85ab	0.97b	4.61b	4.87c	0.92ab	0.55bc	8cd	10b	14.23b	11.93b	21.93c	20.08d	1.81c	2.11b
Sugar beet (1)	36.67c	24.87b	0.83ab	1.03b	5.63a	5.54b	1.06a	0.66b	9bc	10b	17.52a	15.06a	31.14a	32.86a	2.97a	3.16a
Sugar beet (2)	32.33d	24.50b	0.93a	1.60a	6.13a	6.29a	1.08a	1.26a	10ab	11ab	16.40a	12.59b	26.28b	29.92b	2.77ab	2.93a
Garden beet	24.00e	22.17c	0.77ab	0.40c	2.93d	3.73d	0.42c	0.43c	11a	12a	12.33c	8.61c	16.94d	12.20e	1.70c	1,61c
Leaf beet	22.17e	22.00c	0.68b	0.35c	2.07e	2.72e	0.42c	0.25d	8d	10b	16.28a	12.12b	22,21c	23.35c	2.53b	2.35b
L.S.D. at 0.05	2.52	2.31	0.18	0.15	0.68	0.51	0.17	0.18	1.03	1.51	1.86	1.43	3.15	2.43	0.39	0.33
	Morphological characteristics at 80 days															
Fodder beet (1)	58.67a	55.0a	2.7c	1.6b	66.30c	35.49d	12.28c	7.49d	17bc	15c	25.01d	21.15	59.90f	36.09d	7.71d	4.8e
Fodder beet (2)	56.0b	51.33b	3.1b	1.63b	66.53c	42.01c	13.69bc	10.72c	17b	16c	27.59cd	24.75c	134.28d	78.10b	11.5c	8.52c
Sugar beet (1)	54.0b	46.67c	3.2b	2.2a	134.96b	52.55b	15.14b	12.98b	19a	16bc	61.5a	27.2	260.13a	84.01a	38.73a	10.44a
Sugar beet (2)	49.0c	44.5d	3.9a	2.53a	168.79a	55.97a	25.31a	16.33a	19a	17ab	50.01b	26.53b	181.94b	83.57a	26.08b	9.94ab
Garden beet	34.33e	39.5e	1.93d	1.33b	29.71d	30.19e	6.73d	7.06e	19a	1ba	24.36d	20.17d	89.61	47.42c	8.69	7.82d
Leaf beet	43.36d	43.4d	1.08e	1.17b	15.81e	12.75f	3.1e	2.43f	16c	15c	28.95c	24.88bc	169.91c	81.56ab	11.84c	9.88b
L.S.D. at 0.05	2.08	1.77	0.39	0.47	5.49	1.24	2.54	0.38	1.19	1.62	3.85	1.76	5.81	3.95	1.42	0.54
	Morphological characteristics at 110 days															
Fodder beet (1)	32.4a	42.17a	5.1b	3.07c	160.4d	82.88c	25.33d	17.41b	21bc	21bc	41.87d	25.48d	164.13d	66.82d	22.16d	9.26d
Fodder beet (2)	32.5a	40.30a	5.37ab	4.0b	199.5c	95.33b	37.01c	18.68b	22b	21bc	57.54c	29.16c	353.4b	110.76c	31.16c	19.15b
Sugar beet (1)	29.83b	36.33b	5.63ab	4.33ab	247.79b	122.21a	53.28b	29.96a	22b	22b	79.46a	41.48a	396.75a	256.33a	47.70a	23.2a
Sugar beet (2)	27.9b	35.17b	6.1a	4.7a	284.78a	123.29a	64.5a	31.4a	23b	22b	67.93b	36.06b	379.62ab	135.91b	48.98a	22.62a
Garden beet	25,07c	31.33c	4.0c	2.87c	130.47e	61.04d	23.88d	15.52c	25a	23a	37.27	23.01d	243.97c	108.02c	22.93d	15.34c
Leaf beet	28.5b	28.5d	2.07d	1.93d	46.08f	49.16e	7.21e	7.96d	20c	20c	58.58bc	34.98b	381.55ab	132.55b	40.54b	19.98b
L.S.D. at 0.05	2.06	2.56	0.76	0.41	14.44	7.60	3.47	1.62	1.51	1.33	9.52	2.66	37.53	14.84	2.99	1.08

Table (2): Physiological characteristics of leaves in some cultivated beet groups at 50, 80 and 110 days from sowing during the 2019/2020 and 2020/2021 seasons.

Varieties	Physiological characteristics at 50 days											
	Chlorophyll A (mg/g F.W.)		Chlorophyll B (mg/g F.W.)		Total Chlorophyll (mg/g F.W.)		Nitrogen (N %)		Potassium (K %)		Phosphorous (P %)	
	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
Fodder beet (1)	0.538de	0.597e	0.163d	0.188e	0.697e	0.785e	0.368c	0.333b	5.38e	6.47e	0.236c	0.239c
Fodder beet (2)	0.533e	0.585f	0.156e	0.184e	0.687f	0.769f	0.333d	0.298c	7.25c	8.28c	0.233c	0.161d
Sugar beet (1)	0.545cd	0.611d	0.173c	0.208d	0.717d	0.819d	0.402a	0.333b	6.76d	7.82d	0.153e	0.145f
Sugar beet (2)	0.555c	0.629c	0.174bc	0.215c	0.725c	0.844c	0.403a	0.403a	8.67a	9.18a	0.180d	0.151e
Garden beet	0.579b	0.647b	0.178b	0.219b	0.757b	0.866b	0.393b	0.333b	7.45b	8.52b	0.434a	0.291a
Leaf beet	0.598a	0.703a	0.205a	0.244a	0.802a	0.947a	0.263e	0.282d	6.68d	7.78d	0.333b	0.273b
L.S.D. at 0.05	0.01	0.004	0.004	0.004	0.007	0.007	0.007	0.008	0.18	0.21	0.005	0.004
	Physiological characteristics at 80 days											
Fodder beet (1)	0.686d	0.672d	0.226d	0.228d	0.912d	0.900e	0.403d	0.403d	8.9e	9.33e	0.313c	0.346c
Fodder beet (2)	0.611e	0.664e	0.219e	0.224d	0.831e	0.887f	0.381e	0.403d	10.05c	10.67c	0.277d	0.323d
Sugar beet (1)	0.704c	0.683c	0.236c	0.233c	0.940c	0.919d	0.520a	0.465a	9.37d	9.83d	0.256e	0.234f
Sugar beet (2)	0.704c	0.720b	0.236c	0.234c	0.941c	0.954c	0.473b	0.437b	13.2a	16.45a	0.247e	0.265e
Garden beet	0.720b	0.733a	0.244b	0.253b	0.964b	0.987b	0.438c	0.414c	12.1b	13.13b	0.638a	0.379a
Leaf beet	0.727a	0.737a	0.250a	0.287a	0.977a	1.024a	0.331f	0.355e	9.9d	10.47c	0.353b	0.362b
L.S.D. at 0.05	0.003	0.004	0.004	0.004	0.005	0.006	0.007	0.006	0.16	0.21	0.012	0.004
	Physiological characteristics at 110 days											
Fodder beet (1)	0.705e	0.722e	0.240e	0.257c	0.946e	0.979e	0.473d	0.508c	11.43d	12.08e	0.416c	0.405b
Fodder beet (2)	0.694f	0.711f	0.238e	0.245d	0.932f	0.957f	0.473d	0.508c	10.88e	10.78f	0.282d	0.383c
Sugar beet (1)	0.717d	0.726d	0.249d	0.263b	0.966d	0.988d	0.636b	0.543b	15.5b	18.65a	0.257e	0.286e
Sugar beet (2)	0.731c	0.736c	0.259c	0.267b	0.991c	1.003c	0.683a	0.569a	16.73a	15.77d	0.261e	0.362d
Garden beet	0.735b	0.741b	0.267b	0.301a	1.003b	1.042b	0.543c	0.510c	13.98c	17.85b	0.671a	0.613a
Leaf beet	0.747a	0.750a	0.277a	0.303a	1.022a	1.053a	0.473d	0.507c	13.8c	16.67c	0.457b	0.406b
L.S.D. at 0.05	0.004	0.004	0.004	0.005	0.005	0.006	0.009	0.005	0.19	0.20	0.012	0.004

3.3 The anatomical structure of roots

The data contained in Table (3) and Figure (1) showed that the highest values for Ø of root were recorded for the two sugar beet cultivars (4.285 and 4.333 mm, respectively), while the lowest values were recorded for the garden beet cultivar (3.024 mm). The highest values of parenchyma layer thickness were also recorded in the two sugar beet cultivars (410.88 and 448.48 µm, respectively), while garden beet showed the lowest values (228.6 µm). The highest values of cortex thickness were recorded in the two fodder beet cultivars (269.22 and 280.71 µm, respectively), and the leaf beet showed the lowest values (180.81 µm). While the highest values for the Ø of V.C were recorded in garden beet (976.08 µm), and the two sugar beet cultivars recorded the lowest values (754.22 and 687.74 µm, respectively). The two sugar beet cultivars recorded the largest number of growth rings (4 rings), while the other cultivars had a smaller number of growth rings (3 rings), and the rings were thicker in the two sugar beet cultivars (where the thickness of the second growth ring reached 520.58 and 496.01 µm, respectively) and were less thickest in the garden beet cultivar (the thickness of the second growth ring was 275.68 µm). The two cultivars of sugar beet also recorded the highest values in xylem arm length (142.79 and 122.32 µm, respectively), while leaf beet recorded the lowest values (89.56 µm), on the other hand, fodder beet given the highest values for the Ø of Xylem big vessels, (79.05, 61.90 µm, respectively) and leaf beet scored the lowest values (50.96 µm). These results show that sugar beet cultivars are characterized by larger Ø of the root, increased thickness of the stored parenchyma tissue, and an increase in the number of growth rings, which helps in increasing the stored sucrose and thus reducing the cortex thickness. This agrees with what was reached by El-Emary (2004), El-Nady (2006) and Biancardi et *al.* (2020).

Table (3): Anatomical structure of root for some Beet cultivated groups at 65 days from sowing during the 2020/2021 season.

Ch. / Varieties	Ø of root (mm)	Parenchyma layer thickness (µm)	Cortex thickness (µm)	Ø of V.C (µm)	No. of growth rings	Growth rings thickness (µm)	Xylem arm length (µm)	Ø of xylem big vessels (µm)
Fodder beet (1)	4.046c	405.14c	280.71a	823.36b	3b	417.49d	118.41b	79.05a
Fodder beet (2)	3.957d	336.48d	269.22b	803.41b	3b	417.43d	106.42d	61.90b
Sugar beet (1)	4.285a	410.88b	256.89c	754.22d	4a	520.58a	142.79a	58.14c
Sugar beet (2)	4.333a	448.48a	214.28d	687.74e	4a	496.01b	122.32b	53.11d
Garden beet	3.024e	228.65f	258.62c	976.08a	3b	275.68e	113.67c	51.81d
Leaf beet	4.162b	323.38e	180.81e	801.15c	3b	465.69c	89.56e	50.96d
L.S.D. at 0.05	0.51	2.59	2.08	8.40	0.89	3.78	4.12	2.56

Ø of root = diameter of the root, Ø of V.C. = diameter of the vascular cylinder, Ø of Xylem big vessels = diameter of xylem big vessels, No. of growth rings = number of growth rings.

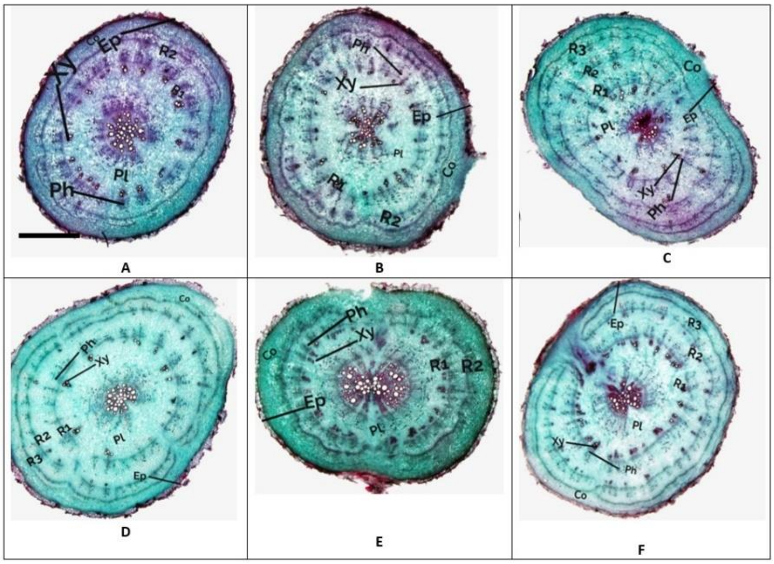

Figure (1): Root cross-sections for some Beet cultivated groups ; A (Fodder beet 1), B (Fodder beet 2), C (Sugar beet 1), D (Sugar beet 2), E (Garden beet), and F (Leaf beet) during 65 days from sowing (Ep: Epidermis tissue, Co: cortex tissue, Pl: parenchyma layer, R1: supernumerary cambium ring No. 1, R2: supernumerary cambium ring No. 2, R3: supernumerary cambium ring No. 3, Ph: phloem tissue, Xy: xylem tissue). Par = 1mm.

3.4 The anatomical structure of leaves

The data contained in Table (4) and Figure (2) showed that the highest values of the midrib thickness were recorded in the two sugar beet cultivars (1272.32 and 1227.23 µm, respectively), while the two fodder beet cultivars recorded the lowest values (916.22, 945.40 µm, respectively). Leaf beet recorded the highest values for mesophyll tissue thickness (683.71 µm), while the lowest values were recorded in the two sugar beet cultivars (330.42 and 324.65 µm, respectively). The two sugar beet cultivars also given the highest values for Ø of V. C (329.65 and 382.06 µm, respectively), and the lowest values were recorded in the leaf beet cultivar (284.19 µm). The highest values for V.B. thickness were recorded in the two sugar beet cultivars (206.27 and 209.95 µm, respectively), while the highest values were recorded for Xylem arm Length in the garden beet cultivar (158.42 µm). The two fodder beet cultivars given the lowest values in V.B. thickness (158.22 and 150.42 µm, respectively) and the xylem arm length (113.62 and 118.18 µm, respectively). Thus, the blade of the leaf beet is thick and the neck is flat, while the rest of the varieties have the blade less thick and the neck is semi-cylindrical. This agrees with what was reached by El-Nady (2006).

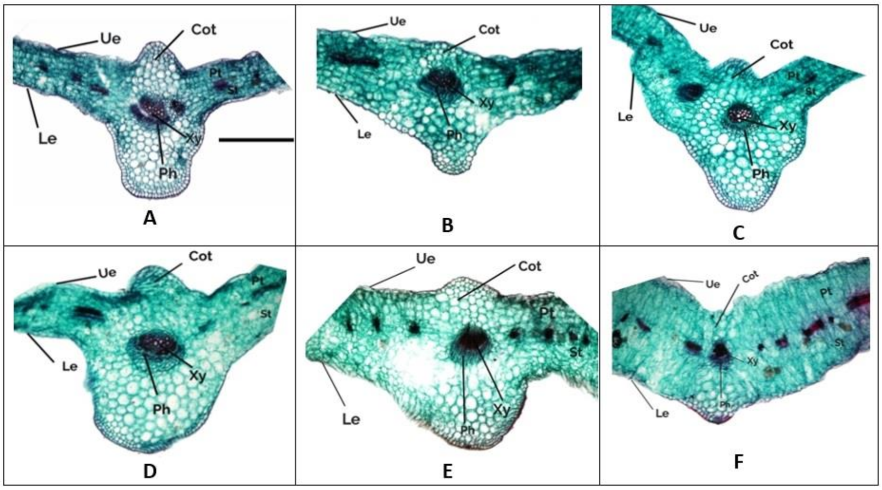

Figure (2): Leaf cross-sections for some Beet cultivated groups, A (Fodder beet 1), B (Fodder beet 2), C (Sugar beet 1), D (Sugar beet 2), E (Garden beet), and F (Leaf beet) during 65 days from sowing (Ue:Upper Epidermis tissue, Le: Lower Epidermis tissue, Pt: Palsied tissue, St: Spongy tissue, Cot: Collenchyma tissue, Ph: phloem tissue, Xy: xylem tissue). Par = 500 µm.

Table (4): Anatomical structure of leaves for some cultivated beet groups at 65 days from sowing during 2020/2021 season.

Ch. / Varieties	Midrib thickness (µm)	mesophyll tissue thickness (µm)	Ø of V. C. (µm)	V.B. thickness (µm)	Xylem arm length (µm)
Fodder beet (1)	916.22d	366.63d	322.72c	158.22d	113.62d
Fodder beet (2)	945.40d	391.09c	301.90d	150.42e	118.18d
Sugar beet (1)	1272.32a	330.42e	329.65b	206.27a	127.45c
Sugar beet (2)	1227.23b	324.65e	382.06a	209.95a	151.05b
Garden beet	1204.65b	609.00b	316.98c	196.12b	158.42a
Leaf beet	997.95c	683.71a	284.19e	170.91c	126.72c
L.S.D. at 0.05	44.6	9.01	6.07	6.30	4.58

Ø of V. C (µm) = diameter of the vascular cylinder, V.B. thickness (µm) = vascular bundle thickness.

3.5 Stomata

Beet cultivars have three types of stomata: anisocytic (in this type of stoma surrounded by three subsidiary cells of which one is distinctly smaller than the other two.), anomotetracytic (in this type stoma surrounded by four subsidiary cells, These cells show several different patterns), and anomopentacytic (in this type the stoma surrounded by a limited number of subsidiary cells which are quite alike the remaining epidermal cells. The accessory or subsidiary cells are five in number (Van Cotthem, 1970). The data in Table (5) and Figure (3) showed that the highest values of the stomatal density were recorded in the garden beet variety (333.04/mm^2), while the two fodder beet cultivars given the lowest values (138.84 and 114.08/mm^2 respectively). The varieties were distinguished by their inclusion of the three types. In the two types of fodder beetroot, the percentage was (0.200% a 0.656% b 0.144% c, 0.151% a 0.651% and 0.198% c, respectively) and it was in the two beet sugar cultivars (0.307% a 0.568% b 0.125% c), 0.238% a 0.615% b 0.147% c respectively), and it was in the garden beet cultivar (0.278% a 0.619% b 0.103% c), and it was in the beetroot cultivar (0.204% a 0.650% b 0.146% c). As for the stomata width, the highest values of stomata length were recorded in the two fodder beet cultivars (18.63 and 19.13 µm, respectively), and the highest values of stomata width were recorded in the two sugar beet cultivars (4.18 and 4.43 µm, respectively), while the garden beet cultivar The lowest values for the length and width of the stomata opening (13.78 L, 3.09 w µm). These results are in line with El-Nady (2006).

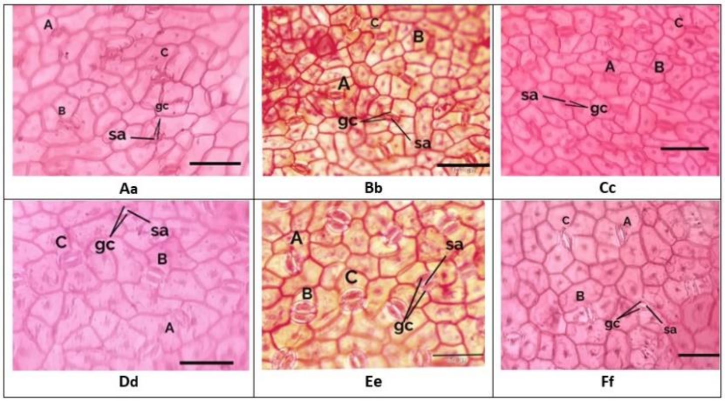

Figure (3): Leaf lower epidermis for some cultivated beet groups; Aa (Fodder beet 1), Bb (Fodder beet 2), Cc (Sugar beet 1), Dd (Sugar beet 2), Ee (Garden beet), and Ff (Leaf beet). (A: anisocytic type, B: anomotetracytic type, C: anomopentacytic type, gc: guard cell, sa: stomatal apertures). Par= 50 µm.

Table (5): Anatomical structure of lower epidermis of the leaf (stomata structure) for some cultivated beet groups during 2020/2021 season.

Ch. / Varieties	Stomatal density in mm^2	Stomata types %			Stomata wideness	
		Anisocytic	Anomotetracytic	Anomopentacytic	Length (µm)	Width (µm)
	Season 2020/2021					
Fodder beet (1)	138.84d	20.0e	65.6a	14.4b	18.63b	3.48c
Fodder beet (2)	114.08e	15.1f	65.1b	19.8a	19.13a	3.68c
Sugar beet (1)	231.55b	30.7a	56.8d	12.5c	15.56c	4.18b
Sugar beet (2)	185.87c	23.8c	61.5c	14.7b	15.12d	4.43a
Garden beet	333.04a	27.8b	61.9c	10.3d	13.78e	3.09d
Leaf beet	186.34c	20.4d	65.0b	14.6b	14.86d	3.95b
L.S.D. at 0.05	15.17	0.2	0.4	0.4	0.344	0.233

3.6 Yield and quality

The data in Table (6) showed highly significant differences in yield and quality characteristics between the studied beet cultivars, where the two sugar beet cultivars recorded the highest values in root sucrose content (17.97%, 17.10% first season, 19.27%, 18.53% second season for the two cultivars, respectively) and crystallized white sugar (15.67%, 14.66% first season, 16.94%, 16.0% second season) and the quality ratio (86.58%, 85.57% first season, 88.10%, 86.77% second season), and the lowest values in the sodium content of the root (1.37%, 1.47% first season, 1.19%, 1.45% second season) and α-amino N (17.97%, 17.10% first season, 19.27%, 18.53% second season for the two varieties, respectively). While the two fodder beet cultivars given the highest values in root content of potassium (7.05%, 4.30% first season, 6.82%, 6.58% second season) and sodium (4.19%, 4.54% first season, 4.87%, 2.86% second season) and the percentage of impurities (4.33%, 3.59% first season, 4.56%, 3.72% second season) and the lowest values in root sugar content (10.73%, 8.43% first season, 10.70%, 10.40% second season) and crystallized white sugar (6.44%, 4.48%.

Table (6): Yield and quality characteristics for some Beet cultivated groups at 200 days from sowing during 2019/2020 and 2020/2021 seasons.

Ch. / Varieties	Pol (%)		ES (%)		K (%)		Na (%)		α-Amino N (%)		Quality (%)		IP (%)	
	Season 2019/2020	Season 2020/2021	Season 2019/2020	Season 2020/2021	Season 2019/2020	Season 2020/2021	Season 2019/2020	Season 2020/2021	Season 2019/2020	Season 2020/2021	Season 2019/2020	Season 2020/2021	Season 2019/2020	Season 2020/2021
	200 days													
Fodder beet (1)	10.73e	10.72d	6.44e	6.16d	7.05a	6.82a	4.19a	4.87a	1.95c	2.79ab	59.6b	58.53d	4.33a	4.56a
Fodder beet (2)	8.43f	10.40d	4.84f	6.68d	4.30b	6.58ab	4.54a	2.86b	2.86b	2.09bc	60.72b	64.4c	3.59b	3.72b
Sugar beet (1)	17.97a	19.27a	15.67a	16.94a	3.82bc	4.22cd	1.37b	1.19c	2.49b	1.86c	86.58a	88.10a	2.31c	2.32c
Sugar beet (2)	17.10b	18.53a	14.66b	16.00a	4.26bc	4.80c	1.47b	1.35c	1.93c	1.43c	85.57a	86.77a	2.44c	2.53c
Garden beet	15.61c	15.93b	13.27c	13.67b	3.61c	3.63d	1.66b	1.55c	2.62b	2.09bc	83.08a	84.80a	2.34c	2.26c
Leaf beet	13.65d	13.39c	10.20d	9.81c	3.91bc	5.95b	3.99a	2.80b	4.76a	3.06a	81.61a	75.44b	3.45b	3.58b
L.S.D. at 5 %	0.85	1.04	0.97	1.22	0.66	0.82	0.88	0.44	0.46	0.85	5.47	5.10	0.36	0.35

Pol % = sucrose percentage, Es %= Extractable sugar percentage, IP %=impurities percentage, Na %= sodium percentage, K %= potassium percentage, α-amino N %= α-amino nitrogen percentage.

First season, 6.16%, 6.68% second season) and quality ratio (59.6%, 60.72% first season, 58.53%, 64.4% second season). While the garden beet cultivar recorded the lowest values in root potassium content (3.61% first season, 3.63% second season) and impurities (2.34% first season, 2.26% second season). The leaf beet given the highest values in root content of α-amino N (4.76 % first season, 3.06% second season). Sugar beet is one of the most important sources of sugar in the world, and therefore is characterized by high sucrose content, low potassium, sodium, and alpha-amino nitrogen levels, and thus the low percentage of impurities, high quality and crystallized white sugar, while fodder beet is characterized by the high percentage of minerals and fibers, which leads to the high percentage of impurities and low percentage of quality, sugar percentage and the percentage of crystallized sugar white. This agrees with what was reached by Martin (1980) and Bojovic *et al.* (2014).

4. Conclusion

The results revealed significant differences between the four groups of cultivated beets in morphological, physiological, anatomical, yield and quality characteristics, which may be useful as a classification guide that enhances the classification of common beets into four cultivated groups and that each group contains different genotype beneath them. The results also indicated the degree of convergence between the four totals and that the garden beet is closer to the sugar beet group, and then to the leaf beet group. On the other hand, we find that the fodder beet group is closer to the sugar beet group, and then to the garden beet group (fodder beet, sugar beet, and garden beet leaf beet). Data recorded that this results in it under the same field conditions (Assiut governorate, Egypt).

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