RESEARCH ARTICLE

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Investigation of yield and quality parameters of some sugar beet varieties in Muş ecological conditions

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Abstract
In plant production, determining the suitable varieties suitable for the location and choosing the varieties with the best performance are among the top priorities. Biplot analysis has become widespread in recent years as an important statistical technique for plant breeders and those working in agricultural research. This study was carried out according to Randomized Complete Block Design with 18 upcountry and 2 abroad registered varieties in Muş location in 2022 year. Yield and quality components were investigated. According to the results of variance analysis, it was determined that there were statistically significant differences at the level of 1% among the varieties in terms of all the traits examined. According to the average data obtained in the study; bifurcation varied between (%) 5.4-17.8, leaf yield 13.54-24.28 t ha^{-1}, root yield 73.42-93.57 t ha^{-1}, biological yield 90.29-118.26 t ha^{-1}, sugar content (%) 16.2-19.0, plant juice purity 82.39- 88.10%, dry matter (%) 16.4-20.1, α-amino N (mg 100g^{-1}) 0.0405-0.0498 and ash (%) varied between 2.49-3.35. According to the results of the research, in terms of root yield, G10 no and G14 no varieties came to the fore in terms of the most stable and examined traits. G12 no variety came to the fore in terms of sugar yield and G19 no variety in terms of sugar content. When the average data of all examined traits are evaluated together, G10, G11 and G14 no varieties are considered as the most stable varieties. However, varieties with high root yield, sugar content and sugar yield are the primary preferences of growers in sugar beet production. When all the data of the varieties used in the research are evaluated together; G2, G4, G8, G10, G11, G12, G14, G15 and G19 no varieties can be recommended for Muş ecological conditions. However, it was concluded that the study should be carried out in the following years for more decisive recommendations.
Keywords: Sugarbeet, Variety, Root yield, Sugar content, Biplot

INTRODUCTION

Sugar beet (*Beta vulgaris* subsp. *vulgaris*) is an important agricultural crop and a nutrient-rich commodity. It is the raw material of many industrial products and is largely used in the production of sucrose, which accounts for about 16% of global sugar production (FAO, 2018; Usmani et al., 2022). Sugar beet is also an industrial plant that has an important role in the socio-economic development of the rural population. Being a hoe plant, taking place in the agricultural rotation system, contributes to the development of sectors such as irrigation, mechanization, transportation, plant protection and fertilization. However, it is a major raw material for cosmetics, alcohol, biofuels and sugar and sugar products. It is intertwined with many different sectors such as meat, milk, medicine and transportation. It is the most important raw material source of bioethanol, which is a source of animal feed and renewable energy (Dohm et al., 2014). The employment it creates in agriculture and industry is so high that it cannot be compared with alternative products, and it adds privilege and an effective social dimension to its activities. Sugar factories are of great importance in terms of reducing regional development disparities in our developing regions and Eastern Anatolia and contributing to employment in rural areas.

Sugar beet production in the world is carried out under climatic and agroecological conditions in many different climatic regions, from irrigated production to precipitation-based production (Hergert, 2010). Sugar beet production in the world is carried out under climatic and agroecological conditions in many different climatic regions, from irrigated production to precipitation-based production (Hergert, 2010). Although the sustainability of sugar beet production in the modern sense is quite high cost, the development in its production tends to increase with the increase in both plant breeding and agronomic developments. There are many opportunities for sugar beet production to be more sustainable and at the same time to produce more (Stevanato et al., 2019).

According to FAOTSTAT data, sugar, a strategic product, was produced in 110 countries around the world in the 2021 production period, with a total of 169 million tons of it being 35.9 million tons from beet and 133.1 million tons from cane. In the world, 253 million tons of sugar beet was produced on 4.4 million hectares of land in 53 countries in 2020, and the average yield was 57 t ha^{-1}. Approximately 80% of the sugar beet produced is produced by Russia, France, Germany, USA, Turkey, Poland, China, Egypt, Ukraine and England, respectively. Turkey ranks 5th in the world in terms of production amount and 4th in the European Continent and meets approximately 9% of the production. Although sugar beet yield in Turkey is quite stable and increasing, it has a moderate yield (55-68 t ha^{-1}) compared to other countries. Sugar beet cultivation in Turkey is carried out intensively in Konya, Eskişehir, Yozgat, Kayseri, Sivas, Aksaray, Afyonkarahisar, Yozgat, Ankara, Tokat, Karaman, Kütahya, Nevşehir and Muş provinces. The cultivation areas of these provinces constitute approximately 77.3% of Turkey's cultivation areas and 80.1% of the total production. Muş province ranks 15th in terms of production amount and 13th in terms of cultivation area among the provinces producing sugar beet in 2021 with a production amount of approximately 278 thousand tons, a cultivation area of 5.6 thousand hectares and an average yield of 56 t ha^{-1} (Yasar, 2022).

Sugar beet production follows a fluctuating course from year to year with the effect of global warming. Among the most important reasons for this are; issues such as supply-demand imbalance, drought and irrigation (Ober & Rajabi, 2010; Ghaffari et al., 2019). It is important to determine the varieties suitable for the regions in order to produce high quality and higher yield sugar beet from the unit area. For this reason, the development of new varieties through breeding studies, the testing of different varieties in different locations and the determination of stable varieties with good performance are a current issue that should be addressed in sugar beet production as in all plant groups.

This study was carried out to determine the appropriate varieties in terms of yield and quality parameters with 20 sugar beet varieties in Muş ecological conditions and to determine the correlation between the investigated traits.

MATERIALS AND METHODS

Materials

In the research, 18 up country varieties and 2 abroad registered varieties were used in the production season of 2022. Some information about the cultivars used in the study is given in Table 1.

Considering the climate data for many years, the province of Muş receives an annual average of 758.9 mm of precipitation. Most of the precipitation is in winter and in the form of snowfall. In this respect, the province of Muş can be described as a snow depot (Table 3). The climate of Muş has a suitable climate especially in terms of sugar yield. The temperature differences between day and night are around 15°C, making it a suitable location for sugar beet production. In Muş, sugar beet cultivation is carried out at the end of March and the beginning of April. Harvest begins in late September and continues until mid-November.

The soil structure of the experiment area has suitable values for the cultivation of sugar beet in terms of clay and organic matter (Table 4).

Method

The study was established in the 2022 sugar beet production season according to the Randomized Complete Block Design with 4 replications. 11 types of root and sugar types and 9 types of root type used in the research were selected (Table 1). Trial sowing was done on April 30, 2022. The seeds used in the experiment were genetic monogerms, 3.25 mm – 4.50 mm calibrated and coated seeds were used. Trial sowing, optimal sowing depth 2-4 cm, row length: 10.0 m, number of rows: 5, row spacing: 0.45 m, above row: 0.18-0.20-0.25 m, in sowing parcel area: 2.25 m x 10.00 m = 22.5 m^2. In the trial, fertilizers were given according to the soil analysis results at the recommended amounts and times for sugar beet planting. In the trial, 120 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O fertilizers were used. Thinning was done at 18-25 cm intervals on rows during weed control and 4-6 true leaf periods. When the soil moisture fell below 50%, 5 irrigations were made with sprinkler irrigation. In the harvest, 2 rows from the sides and 1 m distance from the plot heads were taken as the edge effect and the middle

Table 1. Some information about the varieties used in the experiment

Code	Varieties	Variety owner	Registration year	Breeding country	Type	Root yield (t ha^{-1})	Sugar content (%)	Dry matter rate (%)
G1	Danicia KWS	KWS Türk Tarım Tic. A.Ş -Eskişehir	2015	Germany	Roo and, Sugar	101.54	16,14	18,7
G2	Bernanche	Dirik Dış Ticaret Memduh Zafer Dirik	2016	France	Sugar	93.36	15,12	17,71
G3	Orthega KWS	KWS Türk Tarım Ticaret A.Ş.	2019	Germany	Root	78.67	16,61	19,72
G4	Smilodon	Sesvanderhave TR Tarım Ltd. Şti.	2014	Belgium	Root and Sugar	97.40	17,13	19,72
G5	Cigogne	Dirik Dış Ticaret Memduh Zafer Dirik	2016	France	Sugar	93.52	14,85	17,47
G6	Mohican	Sesvanderhave TR Tarım Ltd. Şti.	2012	Belgium	Root	94.26	14,33	14,78
G7	Exotique	Dirik Dış Ticaret Memduh Zafer Dirik	2018	France	Root and Sugar	83.49	15,78	19,11
G8	Garrot	Dirik Dış Ticaret Memduh Zafer Dirik	2017	France	Root and Sugar	91.93	16,21	19,29
G9	Lizard	Sesvanderhave TR Tarım Ltd. Şti.	2012	Belgium	Root	9310	13,86	14,44
G10	Terranova KWS	KWS Türk Tarım Ticaret A.Ş.	2019	Germany	Root	84.33	16,63	19,70
G11	Emirata	DLF Tohumculuk Tic. Ltd. Şti.	2011	Sweden	Root and Sugar	80.57	18,11	20,15
G12	Chevalier	Dirik Dış Ticaret Memduh Zafer Dirik	2018	France	Root and Sugar	80.20	17,72	20,79
G13	Tuna	Sesvanderhave TR Tarım Ltd. Şti.	2019	Belgium	Root and Sugar	76.22	17,52	20,69
G14	Taurus	Sesvanderhave TR Tarım Ltd. Şti.	2019	Belgium	Root and Sugar	80.33	17,05	20,13
G15	Kuno	Sesvanderhave TR Tarım Ltd. Şti.	2016	Belgium	Root	103.04	13,14	15,44
G16	Premmio	DLF Tohumculuk Tic. Ltd. Şti.	2019	Denmark	Root	76.81	17,89	20,95
G17	MA4094*	DLF Tohumculuk Tic. Ltd. Şti.	--	Denmark	Root and Sugar	--	--	--
G18	Molly	DLF Tohumculuk Tic. Ltd. Şti.	2013	Sweden	Root	99.71	17,22	19,11
G19	MA4071*	DLF Tohumculuk Tic. Ltd. Şti.	--	Denmark	Root and Sugar	--	--	--
G20	Varios	Alfa Tarım Gıda İnşaat Hayvancılık Paz. San. Tic.Ltd. Şti - Balıkesir	2015	Denmark	Root and Sugar	89.39	16,62	19,55

Source: Ankara Variety Registration and Seed Certification Center-2022, *abroad registered

Table 2. Coordinates of the trial area

Location	Altitude (m)	Latitude	Longitude
Muş/TİGEM	1259	38°48’46.32”K	41°31’26.23”D

Table 3. Location climate data

Months	Average Precipitation (mm)		Average Temperature (°C)		Average Relative Humidity (%)	
	Years		Years		Years	
	1964-2022 (l.term)	2022	1964-2022 (l.term)	2022	1964-2022 (l.term)	2022
January	89.5	49.4	-7.1	-7.3	81.8	87.4
February	96.5	44.2	-5.6	-2.9	79.7	90.7
March	108.5	162.6	1.1	-0.1	70.9	89.1
April	101.9	32.0	9.2	11.3	62.1	54.9
May	69.1	91.6	14.8	13.5	58.7	64.1
June	27.1	16.0	20.1	21.1	45.2	43.4
July	7.7	0.0	25.0	25.5	33.9	23.2
August	5.4	0.0	25.0	26.6	30.9	17.3
September	15.6	17.2	20.1	21.4	35.5	25.6
October	62.8	21.4	12.8	15.1	56.0	45.4
November	86.7	42.8	4.7	6.6	68.1	73.7
December	88.1	4.2	-2.6	6.3	79.5	89.5
Average	**758.9**	**395.8**	**9.8**	**11.5**	**58.5**	**58.7**

Source: General Directorate of Meteorology -2022

Table 4. Soil characteristics of the trial field

Location	Physical Analysis					Chemical Analysis					
	Dept. (cm)	Sand (%)	Silt (%)	Clay (%)	pH	Cal. (%)	Salinity %	Organic matter (%)	P_2O_2 kg ha^{-1}	K_2O kg ha-1	Tekstur
Muş/TİGEM	0-30	36.64	17.45	45.91	7.4	0.26	0.40	1.28	1020.00	9080.00	Clayed

Table 5. Variance Analysis 1

Variation Sources	DF	Bifurcation	Leaf yield	Root yield	Biological Verim	Sugar Yield
Variety	19	44,6442**	43,7154**	131,494**	290,236**	4,75624**
Block	3	0,8184	0,6942	41,605	59,542	0,65777
Error	57	0,7418	2,0997	26,606	39,941	1,02008
C.Total	79	892,9764	952,3557	4139,713	7969,749	150,4863
CV (%)		8,24	7,97	6,09	6,15	6,88

***, p<0.01; *0.01<P<0.05; CV: coefficient of variation; DF: degrees of freedom*

Table 6. Variance Analysis 2

Variation Sources	DF	Sugar content	Plant juice purity	Dry matter rate	α-amino N	Ash rate
Variety	19	2,73755**	10,5708**	3,51572**	0,00002**	0,175787**
Block	3	0,38086	1,6046	0,02086	0,000006646	0,021448
Error	57	0,588	1,8627	0,28764	0,00000762	0,059408
C.Total	79	86,67208	311,8352	83,25682	0,000831	6,790555
CV (%)		4,41	1,59	2,53	6,25	8,07

***, p<0.01; *0.01<P<0.05; CV: coefficient of variation; DF: degrees of freedom*

3 rows were harvested. Harvest area: 1.35 m x 8 = 10.8 m^2 and was harvested on October 25, 2022.

Statistical Analysis

The analysis of variance of the obtained data was made with the JMP Pro 13 (© 2023 JMP Statistical Discovery LLC.) statistical package software and the traits found to be important were evaluated and grouped according to the LSD test. In addition, Biplot analyzes of the obtained data were analyzed using Genstat 14th (Copyright © 2000-2022 VSN International Ltd.), using GT (Genotype × Trait) biplot method as suggested by Yan and Thinker (2006). The graphs obtained were interpreted according to the results obtained by the researchers working on different plants.

RESULTS AND DISCUSSION

The mean squares of the results of the analysis of variance of the yield traits examined in the study are in Table 5, the mean of the squares of the variance analysis results of the quality traits are in Table 6, the averages of the yield and quality traits and the resulting groups are in Table 7 and Table 8, and the bilateral relationship between the examined traits. table is given in table 9.

According to the results of variance analysis of yield traits in the study, it was determined that there were statistically significant differences at the level of 1% between varieties in terms of bifurcation, leaf yield, root yield, biological yield and sugar yield.

According to the results of variance analysis of the quality traits in the research, it was determined that there were statistically significant differences at the level of 1% between the varieties in terms of polar ratio, plant juice purity, dry matter ratio, α-amino N content and ash ratio.

The bifurcation rate (%) of the varieties examined in the study varied between 5.4-17.8. The highest bifurcation rate was obtained from Danicia KWS (17.8%) and the lowest from MA4071 (5.4%). Çatal and Akınerdem, (2013) reported in their study that the bifurcation rates of the varieties varied between 9.3% and 24.5%. Yaşar and Kendal (2022), in their study to determine the most suitable sugar beet varieties in Muş conditions, reported that the number of bifurcation beets varied between 3.0 and 36.0 pieces per decare, which is similar to the data we obtained from our study on the number of bifurcation beets.

Leaf yield of the cultivars varied between 13.54-24.28 t ha^{-1} and the highest leaf yield was obtained from Smilodon (24.28 t ha^{-1}) variety and the least leaf yield was obtained from Tuna (13.54 t ha^{-1}). Ada and Akınerdem (2011) obtained the highest and lowest values of 32.73

Table 7. The averages of the examined traits and the resulting groups

Varieties	Bifurcation (%)	Leaf yield (t ha^{-1})	Root yield (t ha^{-1})	Biological yield (t ha^{-1})	Sugar yield (t ha^{-1})
Danicia KWS	17.8 a	17.68 de	80.81 fg	98.50 e-j	13.46 e-g
Bernanche	10.1 fg	23.60 ab	93.30 ab	116.91 a	15.67 bc
Orthega KWS	9.3 gh	14.74 g-ı	79.83 f-h	94.58 g-j	12.90 g
Smilodon	15.2 b	24.28 ab	93.97 a	118.26 a	15.43 bc
Cigogne	10.3 e-g	17.60 de	81.65 e-g	99.26 e-j	13.68 d-g
Mohican	12.3 d	21.77 bc	81.94 d-g	103.71 c-f	13.81 d-g
Exotique	15.9 c	16.87 d-f	73.42 h	90.29 j	13.38 fg
Garrot	10.6 ef	20.97 c	91.11 a-c	112.08 a-c	15.48 bc
Lizard	6.6 j-l	18.44 d	83.92 c-g	102.36 d-h	13.61 e-g
Terranova KWS	10.9 ef	16.88 d-f	86.03 b-f	102.92 d-g	14.75 c-f
Emirata	11.5 de	16.72 d-g	83.65 d-g	100.38 e-j	15.06 b-d
Chevalier	7.6 ı-k	21.28 c	92.95 ab	114.24 ab	17.14 a
Tuna	10.9 ef	13.54 ı	78.18 gh	91.72 ıj	14.37 c-f
Taurus	7.0 jk	16.55 d-g	88.88 a-e	105.44 b-e	15.34 bc
Kuno	11.3 d-f	21.75 bc	88.93 a-e	110.68 a-d	16.21 ab
Premmio	6.4 kl	16.04 e-h	80.39 f-h	96.44 f-j	14.43 c-f
MA4094	7.7 ıj	14.37 hı	80.70 f-h	95.08 f-j	14.40 c-f
Molly	13.7 c	21.37 c	89.21 a-d	110.58 a-d	14.88 b-e
MA4071	5.4 l	14.23 hı	83.55 d-g	97.79 e-j	15.78 a-c
Various	8.6 hı	14.88 f-ı	78.76 f-h	93.65 h-j	13.83 d-g
Means	**10.4**	**18.18**	**84.56**	**102.74**	**14.68**
LSD 0,05	1.22	2.05	7.30	8.95	1.43

LSD: The least significant difference

t ha^{-1}, 19.54 t ha^{-1}, Şatana (2011) 35.92 t ha^{-1}, 19.69 t ha^{-1}. Yaşar et al., (2023) reported in their study that leaf yield varied between 12.38-19.06 t ha^{-1}. The differences in their findings are thought to be due to genotpic variations between varieties and lines, and environmental and climatic factors.

Root yield of cultivars varied between 73.42-93.57 t ha^{-1}. In terms of root yields, the highest root yield was obtained from Smilodon (93.97 t ha^{-1}) variety and the lowest root yield was obtained from Exotique (73.42 t ha^{-1}) variety. Keskin (2018), in his study, reported that the beet yield varied between 77.7-111.7 t ha^{-1}, and in Canıgeniş (2012) 71.0-120.7 t ha^{-1}. Hoffman et al. (2009) reported that they obtained the highest and lowest values of 90.30 t ha-1, 69.20 t ha-1 sugar beet root yield in their study. In similar studies conducted in different ecologies, it is seen that the sugar beet root yield obtained by the researchers varies between 36.60 t ha^{-1} and 99.27 t ha^{-1} (Kurtcebe 1999; Azam Jah et al. 2003; Boyacıoğlu et al. 2014; Sefaoğlu et al. 2016). Yaşar and Kendal (2022) reported that root yield varied between 45.00-117.08 t ha^{-1} in their study. From our research findings, it can be said that the data on root yield is higher than previous studies. This can be explained by the new generation of the varieties and the suitability of Muş ecology for sugar beet farming. 80% of sugar beet yield potential is determined by climate, soil and variety factors (Pidgeon et al., 2001; Yaşar and Ekinci, 2021).

The biological yields of the varieties varied between 90.29-118.26 t ha^{-1}. The highest biological yield was obtained from Smilodon (118.26 t ha^{-1}) and Bernanche (116.91 t ha^{-1}) varieties located in the same group. The lowest biological yield was obtained from Exotique (90.29 t ha^{-1}) variety. Yaşar et al., (2023), in their study with 8 sugar beet genotypes in Muş ecological conditions, reported that the biological yields showed a change of 80.1-104.0 t ha^{-1}. These findings show parallelism with the data obtained in the study.

Sugar yields of the varieties varied between 12.90-17.14 t ha^{-1}. The highest sugar yield was obtained from Chevalier (17.14 t ha^{-1}) variety and the lowest sugar yield was obtained from Orthega KWS (12.90 t ha^{-1}) variety. Tosun et al. (2019) reported that the sugar yield varied between 14.90 and 18.67 t ha^{-1} in their research under Isparta conditions. Yaşar et al., (2023), reported in their study that it varies between 9.91-16.37 t ha^{-1}. The most important factor in sugar beet production is the high sugar yield per unit area. Since the aim in sugar beet cultivation is to produce white sugar, sugar beet root yield and sugar presence should be evaluated together.

When the averages of all cultivars are considered, the bifurcation rate is 10.4%, leaf yields are 18.18 t ha^{-1}, root yields are 84.56 t ha^{-1}, biological yields are 102.74 t ha^{-1}

Table 8. The averages of the examined traits and the resulting groups

Varieties	Sugar content (%)	Plant juice purity (%)	Dry matter rate (%)	α-amino N (mg 100g^{-1})	Ash rate (%)
Danicia KWS	16.7 h-j	87.15 ab	20,6 f-ı	0.0405 f	3.07 a-f
Bernanche	16.8 g-j	83.60 e-g	19,4 j	0.0408 f	3.16 a-d
Orthega KWS	16.2 j	83.56 e-g	21,9 bc	0.0428 c-f	3.01 a-f
Smilodon	16.4 ıj	86.13 bc	21,0 e-h	0.0470 ab	2.80 e-g
Cigogne	16.8 g-j	86.53 ab	20,7 f-ı	0.0433 b-f	3.13 a-e
Mohican	16.9 f-j	82.39 g	20,4 hı	0.0433 b-f	3.10 a-e
Exotique	18.2 a-d	85.45 b-e	22,3 b	0.0455 b-e	3.00 b-f
Garrot	17.0 e-j	88.10 a	21,7 b-e	0.0498 a	3.34 ab
Lizard	16.2 ıj	86.07 bc	20,1 ıj	0.0440 b-f	2.95 d-f
Terranova KWS	17.1 d-j	86.67 ab	21,4 c-e	0.0468 ab	2.75 fg
Emirata	18.1 a-e	86.38 a-c	21,9 b-d	0.0428 c-f	2.79 e-g
Chevalier	18.5 ab	84.52 c-f	22,4 b	0.0458 b-d	2.91 d-f
Tuna	18.4 ab	86.60 ab	20,5 g-ı	0.0440 b-f	2.99 c-f
Taurus	17.3 c-ı	85.27 b-f	20,6 f-ı	0.0440 b-f	2.93 d-f
Kuno	18.2 a-c	86.85 ab	21,9 bc	0.0463 a-c	3.09 a-f
Premmio	18.0 a-f	85.76 b-d	21,3 c-f	0.0423 d-f	3.32 a-c
MA4094	18.0 b-g	82.45 g	21,2 c-g	0.0440 b-f	3.12 a-e
Molly	16.7 h-j	83.34 fg	20,5 g-ı	0.0440 b-f	2.49 g
MA4071	19.0 a	85.77 bd	23,4 a	0.0440 b-f	3.35 a
Various	17.6 b-h	84.04 d-g	21,2 d-h	0.0418 ef	3.04 a-f
Means	**17.4**	**85.3**	**21.2**	**0.0441**	**3.0**
LSD 0,05	1.08	1.93	0.75	0.004	0.34

LSD: The least significant difference

and sugar yields are 14.68 t ha^{-1}.

The sugar content (%) of the varieties examined in the study varied between 16.2-19.0. The highest sugar content was obtained from MA4071 (19.0%) and the lowest in Lizard and OrthegaKWS (16.2%) in the same group. Ada and Akınerdem (2011) think that the differences in the findings of the highest 19.3% and the lowest 16.39% are due to genotypic variations between varieties and lines, and environmental and climatic factors. Çakmakçı and Oral (1998) reported the highest 16.91% and the lowest 14.84%, Toprak et al. (2010) obtained the highest rates of 18.68% and the lowest 15.95%. Yaşar and Kendal (2022), in their study with 8 sugar beet genotypes in Muş ecological conditions, reported that the polar ratio (%) of genotypes varied between 12.8-16.3%. The sugar content in sugar beet varies considerably depending on the variety, plant density, climatic and soil conditions, fertilization, vegetation period, harvest time, and disease and pest population.

The plant juice purity of the varieties varied between 82.39 and 88.10%, and the highest plant juice purity was obtained from Garot (88.10%) and the least from MA4094 (82.45%) and Mohican (82.39%). Doxtator and Bauserman (1952) highest 91.15% and lowest 79.34%, Alfaig et al. (2011) highest 81.18%, lowest 78.59%, Oad et al. (2001) 81.29%, 79.35% and 79.06%, Stevanato et al. (2010) 92.24%, 82.29%, Çakmakçı and Tıngır (2001) 86.33%, 85.84%.

The dry matter rate (%) of the varieties varied between 19.4-23.4. The highest dry matter rate of the varieties was obtained from MA4071 (23.4%) and the lowest dry matter rate was obtained from Bernanche (19.4%) variety. In similar studies conducted in different ecological conditions, Çelikel (1989) reported that the dry matter ratio ranged from 21.5% to 22.5, Kurtcebe (1999) reported that it ranged from 21.8% to 23.7%, and Turgut (2012) reported that it ranged from 16.4% to 17.6%. Çimrin (2001) found the highest dry matter rate 21.4% and the lowest 19.8%, Çakmakçı and Oral (1998), the highest 22.8% and the lowest 21.1%, Yarnia et al. (2008) determined it as 19.44%. As the dry matter rate increases, the sugar content increases at the same rate, since the amount of sugar in the dry matter is calculated as refined sugar content.

The α-amino N (mg 100g^{-1}) rate of the varieties varied between 0.0405 and 0.0498. The highest α-amino N rate was obtained from Garot (0.0498 mg 100g^{-1}) and the lowest α-amino N rate was obtained from Danicia KWS (0.0405 mg 100g^{-1}) and Bernanche (0.0408 mg 100g^{-1}) varieties in the same group. Can (2016), in his research conducted in Yozgat ecological conditions, reported that the α-amino N varies between 0.045 and 0.050. The highest 0.043 and the lowest 0.031 for Şatana (2011), Hoffman et al. (2009) found the ratios 0.022 and 0.017, Rashidi and Abbassi (2011) 0.025, 0.016 ratios in their research. Nitrogenous compounds, which are known as harmful nitrogen and are mostly formed by glutamine and asparagine amino acids and betaine, cannot be precipitated by liming in the sugar process because they dissolve in alkaline solutions and water, and they constitute 5% of the dry matter in molasses (Burba et al. 1996, Mahn et al. 2002). For this reason, it is desired that the nitrogenous compounds, which are expressed as harmful nitrogen, are low in the beet to be processed in the sugar process. The harmful nitrogen content of sugar beet, which is sensitive to nitrogen fertilization, is healthy and has not experienced drought stress, varies between 1.30-1.70 mmol 100g^{-1} beet (Armstrong and Milford, 1985). However, nitrogen fertilizer applications increase the harmful nitrogen content of sugar beet root and values above 2.86 mmol 100 g-1 beet affect the sugar process negatively (Akyar et al., 1980).

The ash rate (%) of the varieties varied between 2.49-3.35 (%). The highest ash rate was obtained from MA4071 (3.35%) and the lowest ash rate was obtained from Molly (2.49%). Şatana and Atakış (1999) found the highest ash rate of 2.47% and the lowest 0.90%, Alfaig et al. (2011) found the highest 0.651% and the lowest 0.560% values.

Table 9. Correlation values of the bilateral relations between the examined traits

Examined traits	Bifurcation (%)	Root yield (t ha^{-1})	Leaf yield (t ha^{-1})	Biological yield (t ha^{-1})	Sugar yield (t ha^{-1})	Sugar content (%)	α-amino N (mg 100g^{-1})	Ash rate (%)	Dry matter rate (%)
Root Yield	-0.0141								
Leaf yield	0.3403**	0.5802**							
Biological yield	0.1139	0.7164**	0.7216**						
Sugar yield	-0.1674	0.7832**	0.3699**	0.531**					
Sugar content	-0.2255	-0.2085	-0.2475	-0.2047	0.4431**				
α-amino N	0.0294	0.2148	0.1739	0.1586	0.2299*	0.0617			
Ash rate	-0.3024**	-0.0585	-0.1531	-0.1499	-0.0233	0.0386	0.0191		
Dry matter rate	-0.1082	-0.0962	-0.1594	-0.1712	0.1807	0.423**	0.2315*	0.1529	
Plant juice purity	0.1548	0.0165	-0.0331	-0.002	0.0437	0.0493	0.1079	0.0224	0.5055**

***:%1; *: %5 statistically significant at the level*

The differences in their findings are thought to be due to genotypic variations between cultivars and lines, and environmental and climatic factors.

When the averages of all varieties are considered, the sugar content is 17.4%, the plant juice purity is 85.3%, the dry matter rate is 21.2%, the α-amino N rate is 0.0441 mg $100g^{-1}$ and the ash rate is 3%.

When the correlation values of the bilateral relations between the examined traits are examined; between bifurcation rate and leaf yield, root yield and leaf, biological and sugar yields, sugar yield and sugar content, between sugar content and dry matter rate, and between dry matter rate and plant juice rate at the level of 1%. It was determined that there was a significant and positive relationship. It was determined that there was a statistically significant and negative relationship at the 1% level between bifurcation and ash rate. It was determined that there was a statistically significant and positive correlation at the 5% level between α-amino N and dry matter rate.

GGE biplot analysis

The variety*trait biplot technique uses the angles between the vectors of the traits to explain the relationship between two traits or a trait with other traits, and the location of the region where the cultivars are located depending on the traits (Figure 1). Many researchers have stated in different studies that there is a positive relationship between the vectors of two traits as the angle value (>0--<90°) gets narrower, and a negative relationship as the angle value (90°>-<180°) increases (Curcic et al., 2018; Yaşar and Kendal, 2022; Yaşar, 2023). Many researchers have reported that this technique is beneficial in the results of their research on this subject. (Gauch, 2006; Xu et al., 2014; Movahedi et al., 2020; Khan et al., 2021; Yaşar, 2023).

When Scatter Plot Figure 1 is examined; It is seen that there is a positive relationship between biological yield and root yield, leaf yield and sugar yield. At the same time, it is seen that there is a negative relationship between root yield and sugar content. This is in agreement with the data in Table 9. In terms of root yield, G10 and G14 varieties stand out in terms of the most stable and examined traits. It was determined that the most suitable variety in terms of sugar yield traits was G12, and the most suitable variety was G4 in terms of leaf yield traits. G19 variety stands out in terms of sugar content (Figure 1).

With the sector analysis, both the traits can be grouped and the most suitable varieties can be determined for each sector and trait group (Figure 2). In the research; The bifurcation rate trait is associated with G2, G6, G9 and G18 in the 1st sector, root yield, biological yield and leaf yield traits are associated with the G4 and G14 varieties in the 2nd sector, sugar yield and α-amino N rate traits are in the 3rd sector and G8, G12 and G15 varieties in sector 4 and sugar content, dry matter rate, plant juice purity and ash rate in sector 5 and associated with G16, G11 and G19 varieties. Other varieties, on the other hand, took place in sectors 6, 7, 8 and 9 and were not associated with any traits (Figure 2).

The average (vertical) and stability (horizontal) curves are created by using the average data of all the traits examined in the research with the Ranking biplot method, and information is given about the stability of the varieties according to these curves (Figure 3). Accordingly, in Figure 3, G10, G12 are the most stable varieties in terms of all traits, as they are located both above the mean curve (horizontal) and close to the stability curve (vertical). G8, G11 and G10 seem to be the suitable varieties, because they located the above or mean line of data. Other varieties are not considered suitable for Muş ecology, but it would be more accurate to repeat the experiment in the following years in order to get more stable results.

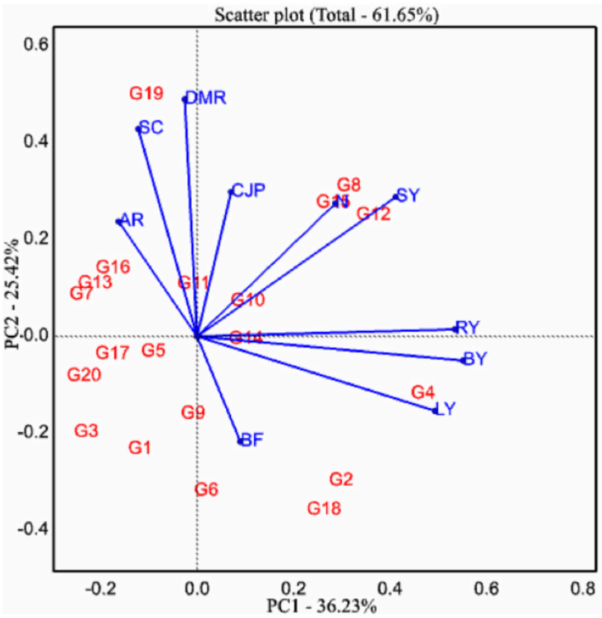

Figure 1. The relationship between varieties and traits.

According to the Comparison method, an ideal center was created according to the average of the traits and the varieties were ranked according to this center (Figure 4). Accordingly, G8, G12 and G15 varieties stand out as the most ideal varieties because they are located close to the ideal genotypes. In addition, G10, G11 and G14 varieties can be recommended as they can be considered close to the ideal genotypes. In addition, G2, G4 and G19 varieties were found to be suitable varieties because they were above the average curve.

It can be said that when recommending varieties in plant production, it is necessary to choose varieties that are located in the ideal center or close to the center and above the average curve, and varieties that are located below the average curve should not be recommended. When these graphs are examined, they can be evaluated according to the places where the varieties are located and their distance or proximity to the traits. It has also been found that it is very convenient for us to determine the genotypes to be selected and eliminated by easily observing the genotypes above and below the mean vertical curve. These results are confirmed by the results of many researchers. (Jockovic et al., 2019; Ghaffari et al., 2021; Gholizadeh et al., 2022; Yaşar, 2023).

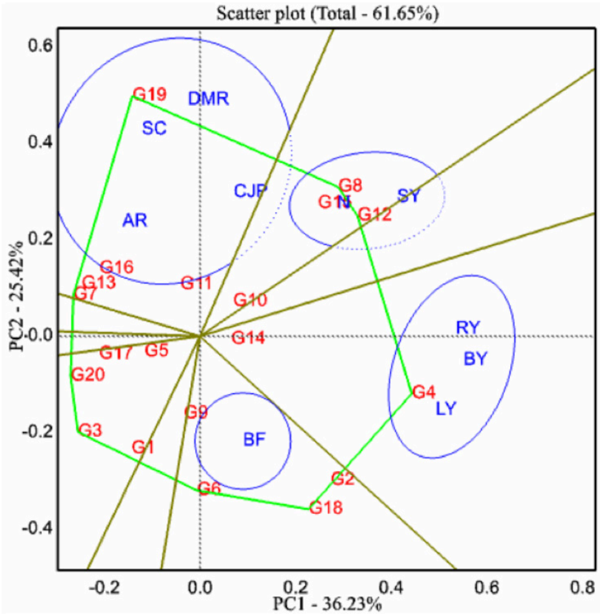

Figure 2. Grouping of varieties in terms of traits.

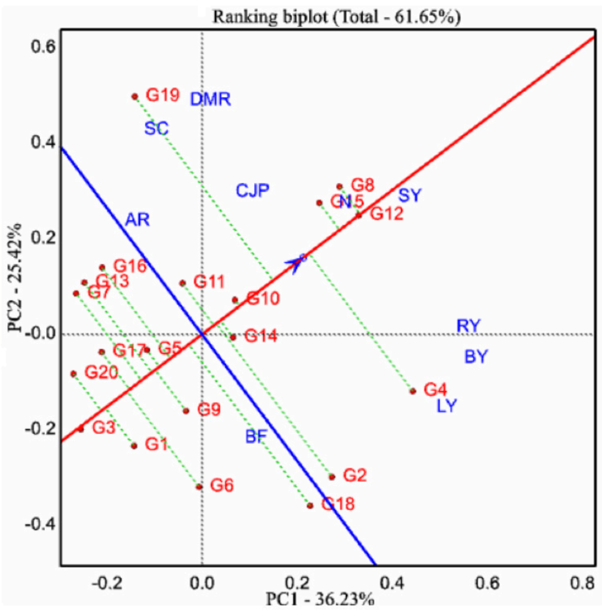

Figure 3. Ranking of varieties in terms of traits.

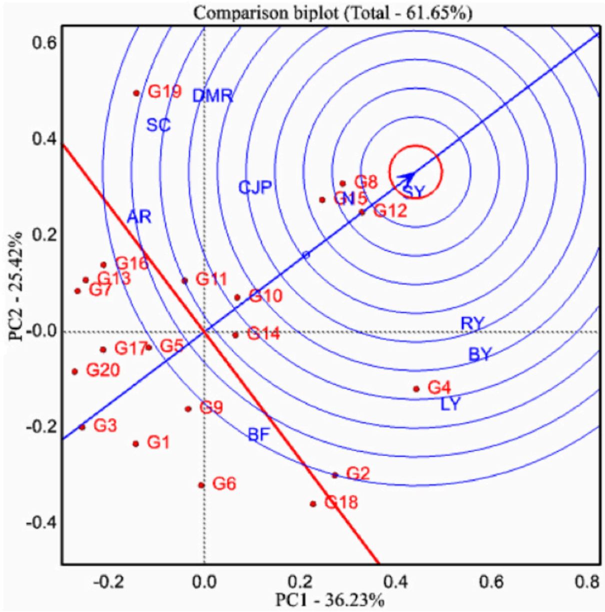

Figure 4. Ranking of vareties according to ideal center.

BF: *bifurcation;* ***RY:*** *root yield;* ***LY:*** *leaf yield;* ***BY:*** *biological yield;* ***SY:*** *sugar yield;* ***SC:*** *sugar content;* ***N:*** *α-amino N;* ***AR:*** *ash rate;* ***DMR:*** *dry matter rate:* ***CJP:*** *plant juice purity.*

CONCLUSION

In this study, In the study carried out with a total of 20 varieties, 18 registered in Türkiye and two registered abroad were tested in the 2022 sugar beet production season in Muş ecological conditions, all cultivars used in the study performed above the Muş sugar beet yield average. According to the results of the research, in terms of root yield, G10 and G14 varieties came to the fore. G12 variety came to the fore in terms of sugar yield and G19 variety in terms of sugar content. When the average data of all examined traits are evaluated together, G10, G11 and G14 varieties are considered as the most stable varieties. However, varieties with high root yield, sugar content and sugar yield are the primary preferences of growers in sugar beet production. It can be said that when recommending varieties in cultivation, it is necessary to choose varieties that are located in the ideal center or close to the center and above the average curve, and varieties that are located below the average curve should not be recommended by biplot tecnique. When all the data of the varieties used in the research are evaluated together; Chevalier, Garrot, Kuno, Smilodon, Terranova KWS, Taurus, Emirata, Bernanche and MA4071 varieties can be recommended for Muş ecological conditions. However, it was concluded that the study should be carried out in the following years for more decisive recommendations.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Ethics committee approval is not required.

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Data availability

Not applicable.

Consent for publication

Not applicable.

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