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PHYSIOLOGICAL AND BIOCHEMICAL COMPOSITION OF SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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SUMMARY

The evaluation of sunflower (*Helianthus annuus* L.) cultivar leaves belonging to different exotic and local genotypes for physiological traits, viz., chlorophyll a and b, total chlorophyll, carotenoid pigments, and concentration of total pigments transpired spectrophotometrically. The exotic sunflower genotypes used in the study consisted of 9859 (USA), 30837 (Australia), 33673 (France), 9843 and 30835 (Turkey), 9853 and 9848 (Russia), and a local cultivar Jakhongir (Uzbekistan). In the budding phase, the exotic accession 33673 (France) showed higher contents of chlorophyll a and b, carotenoids, and total pigments (17.8 ± 0.55, 6.61 ± 0.40, 5.82 ± 0.19, and 24.47 ± 0.95 mg/ml, respectively). For the flowering phase, exotic genotype 30835 (Turkey) excelled for chlorophyll a and b, carotenoids, and total pigments concentration (17.10 ± 0.37, 6.31 ± 0.24, 5.42 ± 0.24, and 23.41 ± 0.55 mg/ml, respectively). In the ripening phase, the amount of chlorophyll a and carotenoids were 16.64 ± 0.84 and 5.82 ± 0.12 mg/ml, respectively, in genotype 9853 (Russia), and chlorophyll b and total pigments correspond to 6.04 ± 0.33 mg/ml and 21.19 ± 0.57 mg/ml in the local cultivar Jakhongir. No significant quantitative variations were evident for nitrogen content and total protein content in sunflower genotype seeds. However, higher values of total protein content (21.8%) manifested in the exotic genotypes, i.e., 30837 (Australia), 33673 (France), and 9848 (Russia). During 2021, the seed oil content ranged from 31.9% ± 0.51% to 54.4% ± 0.87%, while the highest oil content (54.4% ± 0.87%) emerged in genotype 9853 (Russia). In 2022 planting, the sunflower seeds' highest fat content percentage surfaced in sample 9848 (Russia), 53.99% ± 0.14%. In addition, genotype 9853 (Russia) also contained various micro-macro elements, i.e., Mg, Al, Ca, Fe, Sr, and Ba, compared with the rest of the sunflower genotypes.

Keywords. Sunflower (*Helianthus annuus* L.), spectrophotometer, chlorophyll a and b, carotenoids, general pigment, protein, budding, flowering and ripening phases, micro-macro elements

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Key findings: The sunflower (*Helianthus annuus* L.) exotic and local genotypes revealed varied values of physiological traits, viz., chlorophyll a and b, total chlorophyll, carotenoid pigments, and concentration of total pigments analyzed spectrophotometrically. Nitrogen and total protein content showed no significant differences among all the sunflower genotypes.

INTRODUCTION

In the 21st century due to enhanced population, it is obligatory to increase the production of safe, high-quality, and healthy food to overcome hunger and malnutrition (Amanov *et al*., 2020, 2022; Buronov and Xamroev, 2022). Particularly in Uzbekistan, it is necessary to use the available resources to ensure the guaranteed supply of food products to the population, further increase productivity through applying modern scientific approaches, and create food types resistant to diseases and pests (Fayziev *et al*., 2020; Ramazonov, 2020; Ramazonov *et al.,* 2020; Sobirova *et al*., 2020; Buronov *et al*., 2023; Muminov *et al*., 2023). In the domestic consumer market of the Republic, the task of increasing the production volume of non-traditional oil products reached awareness.

Sunflower (*Helianthus annuus* L.) is a widespread crop on earth rich in nutrients and biologically active substances. Scientific evidence has shown that sunflower seed byproducts benefit several food industries (Guo *et al*., 2017). The sunflower plant grows mainly as a spring-summer crop in rainy conditions (García-Vila *et al*., 2012). As a result, it incurs increasing exposure to adverse effects of climate change, i.e., enhanced temperature, increased Co_2 concentration in the atmosphere, extreme climate risks, and deficit moisture conditions, according to forecasts (Pachauri and Meyer, 2014). In addition, the sunflower also relies on good moisture conditions during flowering and seed-filling stage (Flagella *et al*., 2002; Ebrahimian *et al*., 2019).

Obtaining quality seeds requires harvesting the sunflower after reaching physiological maturity at about 10%-13% humidity (NSAC, 2020). However, young plants are a valuable agricultural material, and green sunflower plants are a rich source of fodder for livestock due to their nutrient quality, i.e., high protein and fat content (Demirel *et al*., 2008; Peiretti and Giorgia, 2010).

Protein is imperative for the body, and many dangerous diseases can occur due to its deficiency (Pokrovsky, 1975). The protein performs more than a hundred essential functions in the human body (Kovaleva, 1998; Polesskaya, 2007). However, excess protein also causes variations in the sensitivity of the nervous system, liver, kidney, and other internal organs to malfunction (Kudryashova, 2005; Shatnyuk and Yudina, 2004). The common sunflower seed, grown and consumed worldwide, supplies enormous nutritious components, including protein, unsaturated fats, fiber, vitamins (especially E), selenium, copper, zinc, folate, and iron. It can have many uses, including as a cooking oil, a roasted or salted snack, dehulled as a confectionary nut, and given the sunflower seed is high in sulfuric amino acids, serves as a widely used meal in both livestock and pet feeds (Alagawany *et al*., 2015; Saif *et al*., 2023).

Sunflower seeds are a source of many vitamins and minerals that can support the human immune system and increase the ability to fight viruses. These include zinc, Vitamin B1 (thiamin), and selenium. Zinc is vital in the immune system, helping the body maintain and develop immune cells. Selenium helps reduce inflammation, fight infection, boost immunity, enhance blood flow, and deliver more oxygen to the body. Minerals also participate in the metabolism process and the construction functions of bones and body tissues (Fedichkina, 2000). Organic compounds formed in photosynthesis are the prime source of life for all living organisms. In photosynthesis, the oxygen released into the atmosphere is necessary for the respiration of all living organisms (Beknazarov, 2009). Photosynthetic pigments (chlorophyll a and b and carotenoids) are diverse substances and chemical structures (Muhamad *et al*., 2014).

Differences in antioxidant activity and phenolic profile of sunflower extracts harvested at five stages of plant growth achieved recognition (Gai *et al*., 2020). Using in vitro assays determined the antioxidants. Indicators such as iron-reducing antioxidant capacity (FRAP) and the ability to oxidize β-carotene and linoleic acid emulsion sustained analysis. The phenol content was highest in the mid-flowering stage of sunflowers. No significant correlation was apparent between the phenol content and antioxidant activity. Based on the above discussion, the presented research sought to assess the physiological and biochemical composition of exotic and local genotypes of the sunflower (*Helianthus annuus* L.).

MATERIALS AND METHODS

The pertinent research on sunflower (*Helianthus annuus* L.) ran in the experimental area of the Department of Biology and Genetics and Evolutionary Biology, Faculty of Natural Sciences, Chirchik State Pedagogical University and in the scientific laboratory of the Molecular Biology and Bioinformatics. The breeding material used in the study comprised seven sunflower exotic genotypes acquired from five different countries: 9859 (USA), 30837 (Australia), 33673 (France), 9843 and 30835 (Turkey), and 9853 and 9848 (Russia), and a local cultivar Jakhongir (Uzbekistan).

In this experiment, screening the different sunflower genotype leaves progressed for the content of chlorophyll a and b and carotenoid pigments. It began with samples taken from 3–4 plant leaves, counting from the point of growth of the plant in the field. The 50-mg weight of each leaf, placed in a test tube, had the sample homogenized in 5 ml of 95% ethyl alcohol solution (Lichtenthaler and Wellburn, 1983; Lichtenthaler, 1987). The homogenate continued centrifugation at a speed of 5000 for 12 min. Determining the amounts of chlorophyll a and b and carotenoids in the resulting extract used an Agilent Cary 60 UV-Vis spectrophotometer at 664, 649, and 470 nm. Based on this indicator, the amounts of chlorophyll a and b and carotenoids in plant leaves attained calculations using the following equations (Sumanta *et al*., 2014):

$$\text{Chlorophyll } \alpha \text{ (mg/g)} = 13.36A664 - 5.19 \times A649$$

$$\text{Chlorophyll } \beta \text{ (mg/g)} = 27.43A649 - 8.12 \times A664$$

$$\text{Carotenoid (mg/g)} = (1000A470 - 2.13 \times \text{Xlo “a”} - 97.63 \text{ Xlo “b”})/209$$

$$F \text{ (Mg/g)} = (V \times S)/P$$

Determination of macro and microelements

The plasma inductively coupled mass spectrometry (ISP-MS) method helped determine various elements, i.e., calcium, phosphorus, magnesium, iron, and iodine in the food products. For this purpose, 0.0500–0.500 g of the tested substance commenced weighing on an analytical scale and placed in a Teflon autoclave container, adding an appropriate amount of purified concentrated mineral acids (nitric acid and hydrogen peroxide). After closing, the autoclave gained placement in a Berghof-programmed (MWS-3+) microwave digester. Determining the appropriate program was according to the type of substance for testing. After decomposition, the materials from the autoclave acquired transfer in 50/100 ml volumetric flasks, bringing it to the required mark by adding 0.5% nitric acid. Detection of substances continued on an ISP-MS spectrometer.

Equipment used

The mentioned analysis utilized the ISPMS NEXION-2000 mass spectrometer, microwave separators (Germany), and various sizes of flasks. The Reagent Multielement standard #3 (29 elements for MS) and the standards, i.e., Mercuric, nitric acid, hydrogen peroxide, distilled water, and argon (gas purity 99, 995%), were also used.

Determination of nitrogen and total protein contents

Kjeldahl is one of the methods used to determine the amount of total proteins. According to this method, the total calculated protein has the amount of nitrogen determining it. The essence of the process is to hydrolyze the organic substances in the sample with the help of concentrated sulfuric acid (amine groups in the protein) to form ammonium sulfate salts.

nitrogenous organic matter + H_2SO_4 $\rightarrow (NH_4)_2SO_4+CO_2+H_2O$

After completing the hydrolysis, the ammonium sulfate formed receives treatment with sodium hydroxide to convert it to ammonia.

$$(NH_4)_2SO_4+2NaOH \longrightarrow Na_2SO_4+2NH_4OH \nearrow 2H_2O \searrow 2NH_3$$

Ammonia or ammonium hydroxide formed, after neutralization, assimilates into the sulfuric acid solution. The remaining acid gets titrated with an alkaline solution. Estimating the amount of nitrogen from the amount of ammonia calculated followed. An accurate sample for analysis came from the average crushed homogeneous specimen of the studied material in a test tube; the error rate should not exceed 0.1%. The sampling progressed to quantitate in a Kjeldahl flask. Later, the experiment advanced according to the protocol and instructions of Metody Kontrolya. (Chemical Factors, 2004).

Processing of the obtained results

The mass fraction of nitrogen (X) in the analyzed sample for calculation used the formula as a percentage of the mass of the specimen by the volume after the titration of the amount of ammonia that has passed through the diluted sulfuric acid.

$$X = \frac{(\mathbf{V_1} - \mathbf{V_0}) * \mathbf{K} * \mathbf{0.0014}}{m} * 100\%$$

The volume of 0.1 mol/l sodium hydroxide solution served to titrate the remaining 0.1 mol/l sulfuric acid solution in sample experiment V0, ml.

Determination of oil in the seed

Seed defatting started in Sokslet, first in acetone and then in ethyl ether. After removing the degreased samples from the apparatus, the seeds underwent drying with the masses of flour and filter paper measured, acquiring the difference between the mass before and after degreasing. This difference in mass helped determine the amount of fat in the seeds as a percentage (Mirkhamidova *et al*., 2002).

The statistical analysis of chlorophyll a and b, total chlorophyll, and carotenoid contents of the exotic and local sunflower (*Helianthus annuus* L.) genotypes obtained according to the existing research employed the analysis of variance (ANOVA) program.

RESULTS AND DISCUSSION

The prevailing research pursued the comparative analysis of the chlorophyll a and b, carotenoid content, and total pigments in the leaves of exotic and local sunflower cultivars (*Helianthus annuus* L.) grown in the field experiment. This study assessed the flowering stage and flowering and ripening phases of the sunflower genotypes (Table 1). According to the results, chlorophyll a content occurred with slightly lower values in the exotic and local (Jakhongir) sunflower cultivars at the initial scalding phase than in the remaining ones. In particular, a high value of chlorophyll a (17.8 ± 0.55 mg/ml) was evident in genotype 33673 (France), while the low value resulted in genotype 9843 (Turkey) (10.7 ± 0.23 mg/ml). In the flowering phase, the chlorophyll a content significantly increased, with a higher amount (17.10 ± 0.37 mg/ml) found in genotype 30835 (Turkey) versus the rest of the accessions. The sunflower genotype 9848 (Russia) was higher at the tillering stage (14.4 ± 0.27mg/ml) compared with the flowering stage (9.36 ± 0.20mg/ml). However, during

Table 1. Concentrations of chlorophyll a and b (mg/ml) in exotic and local cultivars of *Helianthus annuus* L.

No.	Sunflower genotypes	Chlorophyll a (mg/ml)			Chlorophyll b (mg/ml)		
		budding	bloom	ripening	budding	bloom	ripening
		$\bar{X}_{\pm S}\bar{X}$	$\bar{X}_{\pm S}\bar{X}$	$\bar{X}_{\pm S}\bar{X}$	$\bar{X}_{\pm S}\bar{X}$	$\bar{X}_{\pm S}\bar{X}$	$\bar{X}_{\pm S}\bar{X}$
1	Jakhongir (UZ)	14.2±0.31	14.57±0.31	15.15±0.32	5.26±0.20	5.39±0.21	6.04±0.33
2	9843 (Turkey)	10.7±0.23	14.44±0.31	13.41±0.29	3.98±0.15	5.34±0.20	4.95±0.20
3	9859 (USA)	14.1±0.34	16.45±0.36	14.64±0.32	4.97±0.05	6.10±0.22	5.40±0.20
4	30835 (Turkey)	14.4±0.31	17.10±0.37	13.37±0.29	5.34±0.20	6.31±0.24	4.94±0.19
5	30837 (Australia)	14.5±0.31	15.45±0.33	14.20±0.31	5.39±0.22	5.72±0.22	5.25±0.20
6	33673 (France)	17.8±0.55	15.44±0.33	14.23±0.31	6.61±0.40	5.72±0.22	5.26±0.20
7	9853 (Russia)	14.6±0.32	15.93±0.34	16.64±0.84	5.44±0.21	5.89±0.23	3.63±0.17
8	9848 (Russia)	14.4±0.27	9.36±0.20	14.17±0.34	5.30±0.21	3.46±0.14	4.97±0.05

the ripening phase, a decline in chlorophyll a content emerged in all the sunflower genotypes (Table 1). The relevant results reveal a higher analogy with past findings on spectrophotometric analysis of chlorophylls and carotenoids in various species by using extracting solvents (Lichtenthaler, 1987; Sumanta *et al*., 2014).

In *Helianthus annuus* genotypes, spectrophotometric analysis proceeded for the photosynthetic pigment chlorophyll β (Table 1). The highest chlorophyll β appeared in genotype 33673 (France) (6.61 ± 0.40 mg/ml), whereas the low rate of chlorophyll β emanated in genotype 9843 (Turkey) (3.98 ± 0.15 mg/ml). During the flowering phase, chlorophyll β content was the same in all genotypes except genotype 9848 (Russia), which showed the minimum value (3.46 ± 0.14 mg/ml). In the ripening phase, the higher rate of chlorophyll β was apparent in the local sunflower cultivar Jakhongir (6.04 ± 0.33 mg/ml), and the lowest rate came from the genotype 9853 (Russia) (3.63 ± 0.17 mg/ml). Similar results about chlorophyll a and b and carotenoids also resulted in the previous studies on paddy (Muhamad *et al*., 2014).

On the carotenoid content in sunflower exotic and local cultivars analyzed with a spectrometer method, the highest values of carotenoid content were distinct in the sunflower genotype 33673 (France) at the budding phase (5.82 ± 0.19 mg/ml), while the low indicator (3.41 ± 0.15 mg/ml) manifested in the genotype 9843 (Turkey). At the flowering phase, the highest values of carotenoid content (5.05 ± 0.22, 5.20 ± 0.23, and 5.42 ± 0.24 mg/ml) were noticeable in the genotypes 9859 (USA), 30835 (Turkey), and 9853 (Russia), respectively. However, the genotype 9848 (Russia) incurred with the lowest carotenoid content (2.97 ± 0.13 mg/ml). For sunflower genotypes, the accession 9853 (Russia) at the ripening phase showed a slightly higher value of carotenoids (5.82 ± 0.12 mg/ml); yet, all other genotypes showed at par values for carotenoid content (Table 1). In analyzing the photosynthetic total pigments, a sharp difference surfaced among the sunflower genotypes for the said character. In particular, at the budding phase of *Helianthus annuus* L., the highest level of total pigments (24.47 ± 0.95 mg/ml) resulted in genotype 33673 (France), whereas the lowest level (14.74 ± 0.35 mg/ml) in the sunflower genotype 9843 (Turkey) (Table 2). Lichtenthaler and Wellburn (1983) also obtained varied content via total carotenoids and chlorophylls a and b determination of leaf extracts. In the chemical composition analysis, past studies also reported varying green pigments, nutritive values, and fatty acid contents in *Helianthus annuus* during the growth cycle (Peiretti and Giorgia, 2010; Saif *et al*., 2023).

In the presented experiments, the amount of oil content in the seeds of exotic and local sunflower genotypes determined appears in Table 3. From the results, exotic and local sunflower cultivars planted in 2021 had the oil content in their seeds ranging from 31.9% ± 0.51% to 54.4% ± 0.87%. However,

Table 2. Concentrations of carotenoids and total pigments (mg/ml) in exotic and local cultivars of *Helianthus annuus* L.

No.	Sunflower genotypes	Amount of carotenoids			Concentration of total pigments		
		budding	bloom	ripening	budding	bloom	ripening
		$\bar{X}_{\pm S}\bar{X}$	$\bar{X}_{\pm S}\bar{X}$	$\bar{X}_{\pm S}\bar{X}$	$\bar{X}_{\pm S}\bar{X}$	$\bar{X}_{\pm S}\bar{X}$	$\bar{X}_{\pm S}\bar{X}$
1	Jakhongir (UZ)	4.51±0.19	4.61±0.20	4.63±0.04	19.4±0.46	19.9±0.48	21.19±0.57
2	9843 (Turkey)	3.41±0.15	4.57±0.20	4.25±0.19	14.7±0.35	19.1±0.47	18.36±0.44
3	9859 (USA)	4.59±0.15	5.20±0.23	4.64±0.20	19.1±0.29	22.5±0.52	20.04±0.47
4	30835 (Turkey)	4.56±0.20	5.42±0.24	4.23±0.19	19.7±0.46	23.4±0.55	18.31±0.43
5	30837 (Australia)	4.62±0.21	4.90±0.21	4.50±0.20	19.9±0.48	21.1±0.50	19.45±0.46
6	33673 (France)	5.82±0.19	4.88±0.22	4.51±0.19	24.4±0.95	21.1±0.50	19.49±0.46
7	9853 (Russia)	4.65±0.20	5.05±0.22	5.82±0.12	20.1±0.48	21.8±0.52	20.27±1.01
8	9848 (Russia)	4.57±0.19	2.97±0.13	4.59±0.15	19.7±0.45	12.8±0.31	19.15±0.29

Table 3. Oil content in seeds of exotic and local sunflower cultivars.

No.	Sunflower genotypes	Fat content (%) in 2021			Fat content (%) in 2022		
		$\bar{X}_{\pm S}\bar{X}$	S	V %	$\bar{X}_{\pm S}\bar{X}$	S	V%
1	Jakhongir (UZ)	33.80±0.56	1.24	3.67	33.4±0.48	1.07	3.20
2	9843 (Turkey)	40.85±0.73	1.64	4.01	39.73±0.82	1.83	4.60
3	9859 (USA)	31.90±0.51	1.13	3.54	33.8±0.66	1.48	4.37
4	30835 (Turkey)	41.30±0.71	1.58	3.82	39.5±0.28	0.61	1.56
5	30837 (Australia)	44.47±0.76	1.69	3.80	40.04±0.43	0.96	2.39
6	33673 (France)	44.90±0.20	0.46	1.01	41.73±0.73	1.61	3.85
7	9853 (Russia)	54.40±0.87	1.93	3.55	51.3±0.69	1.54	3.01
8	9848 (Russia)	51.90±0.91	2.03	3.91	53.99±0.14	0.97	1.87

Table 4. Nitrogen and total protein content in seeds of exotic and local sunflower cultivars.

No.	Sunflower genotypes	Nitrogen content (%)	Protein content (%)
1	Jakhongir (UZ)	3.08	19.2
2	9843 (Turkey)	2.9	18.1
3	9859 (USA)	3.15	19.7
4	30835 (Turkey)	3.3	20.8
5	30837 (Australia)	3.5	21.8
6	33673 (France)	3.5	21.8
7	9853 (Russia)	3.3	20.6
8	9848 (Russia)	3.5	21.8

genotype 9853 (Russia) showed the highest oil content in the spores (54.4% ± 0.87%), and in the exotic genotype 9859 (USA), the oil content was the least (31.9% ± 0.51%). During 2022, the oil content in sunflower seeds of all the genotypes ranged from 33.4% ± 0.48% to 53.99% ± 0.14%. However, during the second year of studies, the highest oil percentage (53.99% ± 0.14%) was visible in genotype 9848 (Russia), whereas the lowest value (33.4% ± 0.48%) for the said trait exhibited by sunflower local cultivar Jakhongir (Uzbekistan) (Table 3). Previous studies have reported similar usefulness as an oil measure in exotic and domestic sunflowers (Alagawany *et al*., 2015).

Establishing nitrogen and total protein content in the seeds of exotic and local sunflower cultivars (*Helianthus annuus* L.) also evolved (Table 4). A result of the analysis indicated nonsignificant variations in the content of nitrogen content and the total

Table 5a. Chemical elements in seeds of exotic and local sunflower cultivars (mg/gb g/t).

No.	Elements	Li	Be	B*	Na*	Mg*	Al*	P*	K*	Ca*	Sc	Ti*	V	Cr	Mn	Fe*	Co
		0.05-4000	0.05-4000	0.10-4000	0.004-11%	0.004-11%	0.002-20%		0.008-30%	0.002-20%	0.10-4000	0.0006-9%	0.20-4000	1.0-4000	0.002-10%	0.006-30%	0.10-4000
1	Jakhongir (UZ)	1.09	<0.05	161	462	4404	469	3589	11775	3902	0.044	10.7	<0.20	0.551	22.6	175	<0.10
2	9843 (Turkey)	0.379	<0.05	128	548	4451	652	8756	8756	4272	0.052	8.53	<0.20	0.554	20.8	207	<0.10
3	9859 (USA)	0.369	<0.05	140	392	3861	411	3112	9020	3059	0.045	8.31	<0.20	0.609	23.3	164	<0.10
4	30835 (Turkey)	0.263	<0.05	122	381	4195	535	3315	7079	3761	0.041	7.84	<0.20	0.553	22.6	187	<0.10
5	30837 (Australia)	0.403	<0.05	106	326	3611	395	2669	7148	3544	0.068	7.35	<0.20	0.502	21.3	176	<0.10
6	33673 (France)	1.39	<0.05	155	420	3983	453	3179	10179	3964	0.039	8.07	<0.20	0.576	22.5	186	<0.10
7	9853 (Russia)	0.554	<0.05	173	526	5313	678	4353	10142	4932	0.047	10.9	<0.20	0.649	25.2	222	<0.10
8	9848 (Russia)	0.201	<0.05	139	362	4233	465	3448	7322	3905	0.031	8.21	<0.20	0.568	22.4	176	<0.10

No.	Elements	Ni	Cu	Zn	Ga	As	Se	Rb	Sr	Y	Zr*	Nb	Mo	Ag	Cd	In
		1.0-4000	1.0-4000	1.0-4000	1.0-4000	0.10-4000	0.50-4000	0.10-4000	0.10-4000	0.10-4000		0.005-4000	0.10-4000	0.50-10,0	0.005-4000	0.005-4000
1	Jakhongir (UZ)	1.42	28.7	63.9	0.259	<0.10	<0.50	6.05	25.9	<0.10	0.514	0.005	0.817	0.004	0.017	<0.005
2	9843 (Turkey)	1.30	30.9	63.7	0.351	<0.10	<0.50	3.28	30.8	<0.10	0.020	<0.005	0.821	0.006	0.018	<0.005
3	9859 (USA)	1.75	32.0	58.3	0.245	<0.103	<0.50	3.97	22.5	<0.10	0.017	<0.005	0.885	0.005	0.020	<0.005
4	30835 (Turkey)	1.19	31.0	59.6	0.261	<0.10	<0.50	2.87	31.5	<0.10	0.024	<0.005	0.994	0.006	0.018	<0.005
5	30837 (Australia)	1.23	28.0	56.6	0.167	<0.10	<0.50	3.17	28.4	<0.10	0.152	<0.005	1.86	0.008	0.015	<0.005
6	33673 (France)	1.36	23.0	60.7	0.232	<0.104	<0.50	4.06	33.2	<0.10	0.030	<0.005	1.24	0.007	0.016	<0.005
7	9853 (Russia)	1.29	23.4	51.6	0.379	<0.10	<0.50	3.07	36.1	<0.10	0.017	0.006	1.12	0.003	0.019	<0.005
8	9848 (Russia)	1.11	29.5	63.8	0.245	<0.10	<0.50	2.80	32.5	<0.10	0.022	<0.005	0.765	0.004	0.020	<0.005

Table 5b. Chemical elements in seeds of exotic and local sunflower cultivars (mg/gb g/t).

No.	Elements	Sn	Sb	Te	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho
		0.10-10	0.10-4000	0.30-4000	0.02-4000	0.10-4000	0.50-4000	0.04-4000	0.01-4000	0.01-4000	0.01-4000	0.01-4000	0.01-4000	0.01-4000	0.01-4000	0.01-4000
1	Jakhongir (UZ)	<0.10	<0.10	<0.30	0.029	20.6	<0.50	0.233	0.027	0.084	0.013	<0.01	0.012	<0.01	<0.01	<0.01
2	9843 (Turkey)	<0.10	<0.10	<0.30	<0.02	26.9	<0.50	0.015	0.105	0.059	0.012	<0.01	0.012	<0.01	<0.01	<0.01
3	9859 (USA)	<0.10	<0.10	<0.30	<0.02	20.2	<0.50	0.047	0.007	0.023	< 0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4	30835 (Turkey)	<0.10	<0.10	<0.30	0.025	22.2	<0.50	0.112	0.013	0.053	< 0.01	<0.01	<0.01	<0.01	<0.01	<0.01
5	30837 (Australia)	<0.10	<0.10	<0.30	0.035	16.4	<0.50	0.550	0.066	0.230	0.042	<0.01	0.028	<0.01	0.013	<0.01
6	33673 (France)	<0.10	<0.10	<0.30	<0.02	18.5	<0.50	0.166	0.017	0.059	0.011	<0.01	<0.01	<0.01	<0.01	<0,01
7	9853 (Russia)	<0.10	<0.10	<0.30	<0.02	30.3	<0.50	0.198	0.019	0.059	0.011	<0.01	0.010	<0.01	<0.01	<0.01
8	9848 (Russia)	<0.10	<0.10	<0.30	<0.02	20.2	<0.50	0.083	0.011	0,04.	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

No.	Elements	Er	Tm	Yb	Lu	Hf	Ta	W	Re	Pt*	Au*	Tl	Pb	Bi	Th	U
		0.01-4000	0.01-4000	0.01-4000	0.01-4000	0.05-4000	0.04-4000	0.08-4000	0.01-4000	0.05-4000	0.05-4000	0.01-4000	0.01-4000	0.01-4000	0.01-4000	0.01-4000
1	Jakhongir (UZ)	<0.01	<0.01	<0.01	<0.01	<0.05	<0.04	<0.08	<0.01	<0.05	<0.05	<0.01	0.352	<0.01	<0.01	0.025
2	9843 (Turkey)	<0.01	<0.01	<0.01	<0.01	<0.05	<0.04	<0.08	<0.01	<0.05	<0.05	<0.01	0.389	<0.01	<0.01	0.032
3	9859 (USA)	<0.01	<0.01	<0.01	<0.01	<0.05	<0.04	<0.08	<0.01	<0.05	<0.05	<0.01	0.326	<0.01	<0.01	0.026
4	30835 (Turkey)	<0.01	<0.01	<0.01	<0.01	<0.05	<0.04	<0.08	<0.01	<0.05	<0.05	<0.01	0.515	<0.01	<0.01	0.031
5	30837 (Australia)	<0.01	<0.01	<0.01	<0.01	<0.05	<0.04	<0.08	<0.01	<0.05	<0.05	<0.01	0.576	<0.01	<0.01	0.22
6	33673 (France)	<0.01	<0.01	<0.01	<0.01	<0.05	<0.04	<0.08	<0.01	<0.05	<0.05	<0.01	0.423	<0.01	<0.01	0.026
7	9853 (Russia)	<0.01	<0.01	<0.01	<0.01	<0.05	<0.04	<0.08	<0.01	<0.05	<0.05	<0.01	0.395	<0.01	<0.01	0.031
8	9848 (Russia)	<0.01	<0.01	<0.01	<0.01	<0.05	<0.04	<0.08	<0.01	<0.05	<0.05	<0.01	0.370	<0.01	<0.01	0.024

protein in the seeds of exotic and local sunflower cultivars. However, the seeds' total protein of all the sunflower genotypes ranged from 18.1% to 21.8%. In particular, and numerically, the high value of total protein content (21.8%) was evident in genotypes 30837 (Australia), 33673 (France), and 9848 (Russia), and the low indicator was apparent in genotype 9843 (Turkey). Noticeably also was the local cultivar Jakhongir, with a total protein content of 19.2% (Table 4). Previous studies mentioned the inheritance and variability of gliadin proteins in various landraces of cereals (Buronov and Xamroev, 2022; Buronov *et al*., 2023).

It is also well-known that determining the concentration of macro- and micro-elements in the tissues and cells of sunflower plants is of theoretical and practical importance in understanding their response to stress factors caused by external environmental conditions. Biochemical mechanisms of homeostasis life and autotrophic nutrition of the plant organism have led to emerging signs of strong adaptation in biological and ecological properties. Another characteristic of each genotype was that the plants can significantly modify their morphological and anatomical structure in response to biotic and abiotic stress factors. The 61 chemical elements were distinctive for the first time in the sunflower genotypes. However, some metal contents were significantly higher than others, while some elements' amounts occurred in large quantities in the sunflower genotypes of the control variants (Table 5a, b). In particular, the seed genotype 9853 (Russia) contained chemical elements, i.e., Mg, Al, Ca, Fe, Sr, and Ba, in higher quantities than other genotypes. Based on the analysis, it was recognizable that the macro-microelements in sunflower seeds meet freely. At the same time, the quantitative index of macro/microelements in the content of sunflower seeds indicated that the nutritional value was high. Past studies also mentioned the chemical elements, nutritional values, and their importance in sunflower (*Helianthus annuus* L.) and other crop plants (Pokrovsky, 1975; Kudryashova, 2005; Peiretti and Giorgia, 2010).

CONCLUSIONS

The sunflower (*Helianthus annuus* L.) exotic and local genotypes revealed varied values of physiological traits, viz., chlorophyll a and b, total chlorophyll, carotenoid pigments, and concentration of total pigments analyzed spectrophotometrically. However, no significant differences were indicative among all the sunflower genotypes for nitrogen and total protein contents. During 2021, the exotic sunflower genotypes 9853 and 9848 (Russia) showed the highest oil content of 54.4% ± 0.87% and 53.99% ± 0.14%, respectively. In addition, the exotic genotype 9853 (Russia) was also higher in chemical elements, i.e., Mg, Al, Ca, Fe, Sr, and Ba, than the rest of the sunflower genotypes.

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