AgroLife Scientific Journal - Volume 11, Number 2, 2022
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

QUANTITATIVE AND QUALITATIVE INDEXES OF THE FUNCTIONING OF PHOTOSYNTHETIC APPARATUS OF ORNAMENTAL SUNFLOWER PLANTS WITH DIFFERENT SEEDING RATES UNDER CONDITIONS OF THE SOUTHERN STEPPE OF UKRAINE

Oleksandr ZHUIKOV, Sergiy LAVRENKO, Victoria LAVRYS, Natalia LAVRENKO

Kherson State Agrarian and Economic University, Kherson, 23 Stritenska Street, 73006, Ukraine

Corresponding author email: larenko.sr@gmail.com

Abstract

The research revealed the tendency for an increase in the index of the average area of an individual leaf blade when the seeding rate rose from 50 to 60 thous. pcs./ha, and further there was a reduction in this index when the seeding rate increased to 70 thous. pcs./ha. The average index in the variant of the hybrid Teddy F_1 was 72.6 cm^2, Double Sunking F_1 - 70.3 cm^2, Santa Fe F_1 - 70.8 cm^2, respectively. The dependence of the index of leaf blade thickness of sunflower hybrids on the factors under study was analogous: this index was minimal in the variant of the hybrid Teddy F_1 - 0.58 mm, it fell to 0.55 mm in the variant of the hybrid Double Sunking F_1, it was minimal in the variant of the hybrid Santa Fe F_1 - 0.52 mm on the average by Factor B. According to our data, the dependence of the intensity of green color of a leaf blade of sunflower hybrids was similar: this index was not essentially dependent on Factor A, but an increase in the seeding rate caused a reduction in the intensity of green color of leaves in comparison with the sample. If the intensity of the sample color is considered to be 100%, the color of a leaf blade in the variant of the hybrid Teddy F_1 was at the level of 73%, that of the hybrid Double Sunking F_1 - 69%, and that of the hybrid Santa Fe F_1 - 69% of the sample. The least intensity of green color of sunflower leaves was with the maximum seeding rate and did not exceed 62% on the average by Factor A. On the average by Factor B, the hybrid Teddy F_1 was considered to be a leader by the content of green pigment in its leaves - 8.69 mg/g, in the variant of the hybrid Santa Fe F_1 it was 7.45 mg/g, Double Sunking F_1 - 8.02 mg/g. The maximum area of the crop photosynthetic apparatus was formed in the variant of the hybrid Teddy F_1 being 30.7 thous. m^2/ha at the stage of flowering, in the variant of the hybrid Double Sunking F_1 - 29.5 thous. m^2/ha and in the variant of the hybrid Santa Fe F_1 - 26.1 thous. m^2/ha, respectively. In all the variants of the crop hybrids there was a correlation according to which there was an increase in the index of leaf surface area when the seeding rate rose from 50 to 60 thous. pcs./ha, and when there was a further increase in the seeding rate to 70 thous. pcs./ha, vice versa, this index started decreasing considerably. The index of net productivity of photosynthesis reached its maximum values in the variant of the hybrid Teddy F_1 being 1.99 g/m^2/day, on the average by Factor B, that of the hybrid Double Sunking F_1 - 1.93 g/m^2/day and that of the hybrid Santa Fe F_1 - 1.84 g/m^2/day, respectively.

***Key words**: ornamental sunflower, hybrids, seeding rate, leaf surface area, fractional composition of chlorophyll, enzyme content, photosynthetic potential.*

INTRODUCTION

Currently cultivation of multiflorous (ornamental) sunflower as a source of pharmaceutical phyto-raw materials is enjoying increasing popularity in all agro-ecological zones of Ukraine (Safonov, 2008; Zhovtobryukh, 2004). This fact can be explained by the results of the latest research on pharmacological characteristics of the crop, revealing that they essentially improve the state of a human body with a wide range of serious diseases. The possibility of using pharmaceutical raw materials (dry petals of male flowers) in a protocol of treating COVID-19 and related consequences makes the scientific problem of developing a zonal technology for the crop cultivation highly topical (Melnik, 2005). In this aspect, agro-ecological conditions of the Southern Steppe Zone with its essential values of degree days in a growing season, supply of nutrients in the soil, amount of productive precipitation and phyto-sanitary condition of agrocenoses are considered to be fully favorable for obtaining economically efficient yields of phyto-raw materials, and their general ecological condition can be a basis for obtaining medicinal products with organic certification, that transfers the cultivation process to an entirely new economic level (Kostenko et al., 2016; Lykhovyd & Lavrenko, 2017; Safonov, 2008; Zhuykov et al., 2020).

Analysis of the latest studies allows stating that along with the increasing popularization of multiflorous sunflower, in the modern scientific journals there is a lack of information about theoretical and applied aspects of cultivation (Kostenko et al., 2016; Pershin & Pershina, 1995; 1996; 1997; 1998). Those individual attempts of certain economic entities trying to obtain commodity phyto-raw materials of the crop are largely based on empirical principles, i.e. farmers apply certain techniques or even entire technological blocks by the method of analogy, using models of the existing zonal technologies for growing common sunflower, without taking into consideration ecological and biological characteristics of this crop which is new for the domestic crop rotation (Kostenko et al., 2016; Melnik, 2005; Lykhovyd et al., 2022; Pershin & Pershina, 1995; 1996; 1997; Zhuykov et al., 2020). While choosing the issue of the scientific research we were mainly guided by the increasing popularity of ornamental sunflower against the background of insufficient information on individual cultivation techniques and a lack of approbated zonal technologies for obtaining its phyto-raw materials (Pershin & Pershina, 1995; 1996; 1997; 1998).

The purpose of the research was to conduct an ecological-economic trial of the modern varieties of ornamental sunflower against the background of different seeding rates. Taking into account the efficiency indexes of the functioning of the crop photosynthetic apparatus, we examined the following factors: leaf blade area, its thickness, the intensity of green color, pigment-enzyme composition, total leaf area and its dynamics during a growing season, photosynthetic potential and net productivity of the crop photosynthesis.

MATERIALS AND METHODS

The field research was conducted in the research field of Kherson State Agrarian and Economic University (Ukraine, 46.693344109882 N, 32.4823827724609 E, 38.71 37 m above sea level) in 2020-2021.

In order to achieve the outlined purpose of the research, we carried out a two-factor field experiment.

Factor A - hybrid assortment of ornamental sunflower represented by the following hybrids: Teddy F_1, Double Sunking F_1, Santa Fe F_1, and Factor B - crop seeding rate: 50, 60 and 70 thous. pcs. of germinated seeds per ha. There were four replications, the total area of the research field was 0.75 ha, the total area of the first-order plot was 280 m^2, the registered area was 250 m^2. The experimental plots were located by the split plot design with partial randomization.

The soil cover of the territory is represented by chestnut degraded soils with secondary salinity. The content of organic matter (humus) (SSTU 4289:2004, 2004) in the research field in the layer of 0-30 cm ranges from low to medium being within 1.82-2.59 %. The content of slightly hydrolyzed nitrogen (SSTU 7863:2015, 2015) is very low (6.02-8.96 mg/100 g of soil). The soil supply of (SSTU 4114:2002, 2002) mobile phosphorus is low (0.33-1.32 mg/100 g of soil), that of mobile potassium is low (10.8-31.0 mg/100 g of soil). The sum of absorbed cations (Ca^{2+}, Mg^{2+}, Na^{+}) (SSTU ISO 11260:2001, 2001) in the layer of 0-30 cm ranges from 43.831 to 70.440 mg-eq/100 g of soil. Exchangeable magnesium prevails in the composition of exchangeable cations - 12.5-45.0 mg-eq/100 g of soil. Carbonates ($CaCO_3$) (SSTU ISO 10693, 2001) in the layer of 0-30 cm change within 8.2-9.7%. Reaction of the soil solution in the layer of 0-30 cm (SSTU ISO 10390, 2007) is close to neutral (pH_{saline} ranges from 7.32 to 7.53).

The examined hybrids had the following characteristics according to the originators' descriptions:

Teddy F_1 is a hybrid of ornamental sunflower. This is an annual plant with a thick and strong stem, 50-60 cm high, bushy. Capitulum inflorescences are big, double-flowered or semi-double-flowered, the diameter of 15 cm, double petal flowers, bright-yellow (golden-orange) color;

Double Sunking F_1 is a hybrid of ornamental sunflower. This is an annual plant with a thick and strong stem, 150-180 cm high, bushy. Capitulum inflorescences are big, double-flowered or semi-double-flowered, the diameter of 12-15 cm, double petal flowers, bright-yellow (golden-orange) color;

Santa Fe F_1 - is a hybrid of ornamental sunflower. This is an annual plant with a thick and strong stem, 170 cm high, bushy. Capitulum inflorescences are big, double-flowered or semi-double-flowered, the diameter of 15 cm, double petal flowers, bright-yellow (golden-orange) color. The index of leaf surface area was measured with the method of carving, architectonics of a leaf blade was determined with express-scanning, leaf blade thickness was measured with a digital sliding caliper, the content of green pigment and its fractional composition was determined with photometric measurement of spirit extract, the content and fractional composition of enzymes - with photometric measurement of acetone extract with hydrogen peroxide under further photoseparation.

The growing seasons of 2020-2021 had different weather conditions but they were favorable for sunflower cultivation (Table1).

Table 1. Climatic conditions in the years of the research

Year-month	AT, °C	DNI, W/m^2	RH, %	PA, mm	WS, m/sec	ETo, mm
2021-12	1.82	25	93.50	50.6	1.8	11.7
2021-11	6.53	47	87.60	46	1.4	18.0
2021-10	9.91	108	64.54	5.8	1.0	43.4
2021-09	16.04	159	58.39	16.2	1.2	78.3
2021-08	24.54	228	57.82	10.2	1.2	143.0
2021-07	25.70	248	61.47	58.6	0.8	147.0
2021-06	20.87	223	78.62	111	1.3	121.5
2021-05	15.87	232	71.94	64.8	1.7	119.7
2021-04	8.67	167	76.45	42.4	1.6	68.9
2021-03	3.29	114	79.31	43.4	1.9	41.3
2021-02	-0.61	67	85.89	18.4	2.2	19.7
2021-01	-0.61	37	91.06	57.8	1.7	10.7
2020-12	1.97	20	91.27	20.8	2.0	13.4
2020-11	4.81	41	85.76	11.4	1.1	16.8
2020-10	15.55	98	80.92	15.2	1.4	49.6
2020-09	20.17	181	54.46	63.6	1.0	96.6
2020-08	23.18	240	48.36	5.6	1.0	140.7
2020-07	24.12	262	55.02	46.4	1.2	159.3
2020-06	22.26	256	67.09	66.8	1.3	144.5
2020-05	14.70	209	67.41	38.0	1.8	114.6
2020-04	9.57	233	53.50	4.0	2.2	106.5
2020-03	7.31	133	66.04	9.6	2.3	65.6
2020-02	2.68	80	85.53	157.8	2.5	26.0
2020-01	1.27	50	87.25	19.6	1.7	11.5

Note: AT - air temperature; DNI - direct normal irradiance; RH - relative humidity; PA - precipitation amounts; WS - wind speed; ETo - evapotranspiration.
Source: Agrometeorology Station Kherson State Agrarian and Economic University, Ukraine.

RESULTS AND DISCUSSIONS

As the results of our research show, both Factor A (hybrid) and Factor B (seeding rate) had an essential impact on the main indexes of the formation of the crop photosynthetic apparatus. It should be highlighted that it concerns not only quantitative changes in the formation and functioning of photosynthetic surface of sunflower crops, but also substantial qualitative changes in a leaf blade, that was confirmed when analyzing the results of our research on this problem (Table 2). By the index of the average area of an individual leaf blade, there was a tendency for an increase in this index when the seeding rate rose from 50 to 60 thous. pcs./ha, and further, when the seeding rate increased to 70 thous. psc./ha, this index started falling. The average index by the variant of the hybrid Teddy F_1 was 72.6 cm^2, Double Sunking F_1 - 70.3 cm^2, Santa Fe F_1 - 70.8 cm^2, respectively. The dependence of the index of leaf blade thickness of the sunflower hybrids on the examined factors was analogous. Minimum indexes were characteristic of the hybrid Double Sunking F_1 - 0.45-0.63 mm. When growing Teddy F1, the indexes were at the level of 0.52-0.61 mm.

Table 2. Architectonics and pigment-enzyme composition of spongy cell tissue of a leaf at the flowering stage of ornamental sunflower hybrids

Hybrid (Factor A)	Seeding rate, thous. pcs./ha (Factor B)	Average index value							
		Leaf blade area, cm^2	Leaf blade thickness, mm	Color intensity, %	Chlorophyll content, mg/g	Chlorophyll "A", %	Chlorophyll "B", %	Peroxidase, arb. u./g	Catalase, arb. u./g
Teddy F_1	50	72.1	0.58	74	8.11	70.1	29.9	694	1752
	60	72.7	0.61	75	9.02	73.3	26.7	690	1789
	70	74.0	0.52	70	6.22	71.8	28.2	665	1584
Double Sunking F_1	50	72.0	0.58	67	8.28	75.8	24.2	661	1646
	60	75.2	0.63	69	9.31	78.4	21.6	682	1695
	70	63.7	0.45	61	6.06	72.6	27.4	649	1578
Santa Fe F_1	50	71.2	0.61	76	8.87	72.0	28.0	690	1672
	60	71.0	0.57	66	8.82	73.9	26.1	674	1677
	70	70.1	0.55	66	8.37	60.2	39.8	639	1515

Maximum indexes of leaf blade thickness were characteristic of the variant of the sunflower hybrid Santa Fe F_1 - 0.55-0.61 mm.

The dependence of the intensity of green color of a leaf blade of the sunflower hybrids was similar according to our data: this index was not essentially dependent on Factor A, but an increase in the seeding rate caused a reduction in the intensity of green color of the leaves in comparison with the sample. If the intensity of the sample color is considered to be 100%, the color of a leaf blade in the variant of the hybrid Teddy F_1 was at the level of 73%, that of the hybrid Double Sunking F_1 - 69%, Santa Fe F_1 - 69% of the sample. The least intensity of green color of the sunflower leaves was under the maximum seeding rate and did not exceed 62% on the average by Factor A (Table 2).

The intensity of green color of a leaf blade immediately reflects the content of chlorophyll pigment in it that was also confirmed by the results of our research. It was minimum (at the level of 6.55 mg/g on the average by Factor A) in the variant with the seeding rate of 70 thous. psc./ha. On the average by Factor B, the leader in terms of green pigment content in the leaves was the hybrid Teddy F_1 - 8.69 mg/g, it was 7.45 mg/g in the variant of the hybrid Santa Fe F_1 and Double Sunking F_1 - 8.02 mg/g.

A number of scientists state that the total content of green pigment does not ensure high productivity of assimilation processes in the crop leaf apparatus. Fractional composition of chlorophyll and, majorly, the content of the most physiologically active fraction (chlorophyll "A") in it is much more important. According to our data, genetic characteristics of the hybrid and plant density had a considerable impact on redistribution of the fractions of chlorophyll "A" and "B": in all the variants of the hybrids an increase in the seeding rate resulted in a reduction in the share of the fraction "A" in the total pigment composition. The maximum share of the fraction "A" on the average by Factor B» was observed in the hybrid Teddy F_1 (77.4%), Double Sunking F_1 - 73.6% and Santa Fe F_1 - 71.0%.

In modern scientific journals there are evidences of the dependence of anti-stress potential of plants in terms of tolerance to high air temperatures and insufficient moisture supply on the content of enzymes responsible for the intensity of respiration, gas exchange, penetrability of intercellular membranes, water retention ability of intercellular volumes, anti-oxidant properties, drought- and heat-resistance in spongy cell tissue. Some authors emphasize the inhibiting effect of the impact of active ingredients of synthetic pesticides and their metabolites on this process and consider the famous effect of "pesticide stress" to be caused by it. As the data given in Table 1 show, the content of peroxidase in the tissues of ornamental sunflower leaves reached the maximum values in the variant of the hybrid Teddy F_1 and equaled, on the average by Factor B, 690 arb.u./g, Double Sunking F_1 - 664 arb.u./g, Santa Fe F_1 - 668 arb.u./g, respectively. A similar tendency was observed while examining the content of the other enzyme - catalase, being 1708, 1640 and 1621 arb. u./g of raw substance on the average by Factor B.

It is well-known that the most principal criterion for forecasting and evaluating potential productivity of any crop is efficiency of the functioning of its photosynthetic apparatus (Basaliy et al., 2016). Almost any technological element aimed at biologization of sunflower cultivation process has a positive effect on an increase in the area of the crop assimilation activity and leads to an essential increase in the efficiency indexes of its functioning (Bazaliy et al., 2019). The research results given in Table 3 do not contradict them.

Table 3. Dynamics of the formation of leaf surface area of ornamental sunflower hybrids depending on seeding rates, thous. m^2/ha

Hybrid (Factor A)	Seeding rate, thous. pcs./ha (Factor B)	Crop development stage		
		"3 sets of true leaves"	"capitulum formation"	"flowering"
Teddy F_1	50	2.1	22.4	32.2
	60	2.7	25.1	36.2
	70	2.0	19.7	23.8
Double Sunking F_1	50	2.0	22.9	32.7
	60	2.6	24.1	35.2
	70	1.9	17.4	20,5
Santa Fe F_1	50	1.8	20.2	29.0
	60	2.1	23.3	27.9
	70	2.0	18.2	21.4
LSD_{05}, thous. m^2/ha	For average (main) effects	A-1.04; B-1.41		
	For partial differences	A-1.22; B-1.19		

An essential increase in the area of photosynthetic apparatus of an individual plant resulted in a rise in the above index calculated per 1 ha of the area under crops. Its average dynamics in the years of the research is presented in Table 2. Beginning with the stage "3 sets of true leaves", the area of assimilation surface of the crops increased and this index reached its maximum values at the stage "flowering", that was characteristic of all the variants of the crop hybrids. Further this index was not examined since at the stage of full flowering phyto-raw materials were harvested (male flowers). On the average by factor B, the maximum area of the crop photosynthetic apparatus was formed in the variant of the hybrid Teddy F_1 being 30.7 thous. m^2/ha at the flowering stage, in the variant of the hybrid Double Sunking F_1 - 29.5 thous. m^2/ha and in the variant of the hybrid Santa Fe F_1 - 26.1 thous. m^2/ha, respectively. In all the variants of the crop hybrids there was a correlation according to which the index of leaf surface area increased when the seeding rates rose from 50 to 60 thous. pcs./ha, and with a further increase in the seeding rate to 70 thous. pcs./ha, vice versa, this index decreased considerably. It, in its turn, affected the final index characterizing conditions and productivity of the process of plant photosynthetic activity in the research variants - net productivity of photosynthesis (Table 4).

Table 4. Dependence of the main indexes of photosynthetic activity of ornamental sunflower hybrids on seeding rates

Hybrid (Factor A)	Seeding rate, thous. pcs./ha (Factor B)	Photosynthetic potential, thous. m^2/ha × days	Increase in dry biomass for the period, kg/ha	Net productivity of photosynthesis, g/m^2/day
Teddy F_1	50	1382	2270	1.87
	60	1576	2712	2.20
	70	1499	2420	1.90
Double Sunking F_1	50	1474	2419	1.97
	60	1533	2653	2.09
	70	1182	1832	1.78
Santa Fe F_1	50	1411	2021	1.77
	60	1476	2389	2.01
	70	1204	1850	1.73
LSD_{05}	For average (main) effects	A-100.6; B-117.8	A-122.0; B-104.4	A-0.05; B-0.07
	For partial differences	A-66.1; B-89.5	A-118.1; B-96.2	A-0.17; B-0.22

The index of net productivity of photosynthesis reached its maximum values in the variants of the hybrid Teddy F_1 being 1.99 $g/m^2/day$ on the average by Factor B, that of the hybrid Double Sunking F_1 - 1.93 $g/m^2/day$, and that of the hybrid Santa Fe F_1 - 1.84 $g/m^2/day$, respectively.

CONCLUSIONS

An increase in the crop seeding rate from 50 to 60 thous. pcs./ha results in a slight improvement of some efficiency indexes of the functioning of photosynthetic apparatus of ornamental sunflower hybrids and a further increase in the seeding rate to 70 thous. pcs./ha causes a decline in all the indexes (area and leaf blade thickness, the content of green pigment and its fractional composition, the content of the most important enzymes, photosynthetic potential and net productivity of the crop photosynthesis). Among the crop hybrids under study, the hybrid Teddy F_1 was considered to be the leader by the above indexes. It considerably exceeded the corresponding indexes in the variants of the hybrids Double Sunking F_1 and Santa Fe F_1.

REFERENCES

Basaliy, V. V., Domaratsky, Ye. O. & Dobrovolsky, A. V. (2016). Agrotechnical method of prolongation of photosynthetic activity of sunflower plants. *Bulletin of Agrarian Science of the Black Sea Coast*, 4(92), 77–84.

Bazaliy, V. V., Domaratsky, Ye. O. & Kozlova, O. P. (2019). Influence of growth stimulants and biofungicides on the architecture of different sunflower morphobiotypes. *Research and Production Journal: Engineering and Technology*, 2(111), 24-28.

Kostenko, N. P., Greniv, S. M., Pavlyuk, N. V., Matus. V. M., Balikina. V. V., Barban. O. V., Shkapenko. E.A. (2016). Methods of examination of ornamental sunflower varieties (*Helianthus annuus* L. ssp. *Ornamentalis*) for difference, homogeneity and stability. Vinnytsia: FOP Korzun D.Yu., 1129 p.

Lykhovyd, P. V. & Lavrenko, S. O. (2017). Influence of tillage and mineral fertilizers on soil biological activity under sweet corn crops. *Ukrainian Journal of Ecology*, 7(4), 18–24. doi: 10.15421/2017_81.

Lykhovyd, P. V., Vozhehova, R. A., Lavrenko, S. O. & Lavrenko, N. M. (2022). The Study on the Relationship between Normalized Difference Vegetation Index and Fractional Green Canopy Cover in Five Selected Crops. *Hindawi: The Scientific World Journal*, 2022, Article ID 8479424.

Melnik, A. V. (2005). Determining the optimal amount of nutrition and composition of soil mixtures in the cultivation of potted ornamental sunflower. *Collection of scientific works of Uman State Agrarian University*, 61(1), 559-563.

Pershin, A. F. & Pershina, I. M. (1995). Nuclear chlorophyll mutants of sunflower. *Materials of scientific and theoretical. conf. mol. scientists "Problems of genetics, selection and cultivation of oilseeds"* (Zaporozhye, April 5-6, 1994). Zaporozhye: IMC UAAS, 8-9.

Pershin, A. F. & Pershina, I. M. (1996). Gene of pale yellow color of ligulate flowers of sunflower. *Cytology and Genetics*, 30(6), 37-38.

Pershin, A. F. & Pershina, I. M. (1997). Sunflower as an ornamental crop. *Information sheet: Zaporozhye CNTI*, 46-97, 4.

Pershin, A. F. & Pershina, I. M. (1998). Genetic potential of ornamental sunflower. *Proceedings of the III International Conference "Floriculture Today and Tomorrow: Assortment, Technology, Marketing"*, July 17, 1998, Moscow, Main Bot. Garden of the Russian Academy of Sciences, 210-213.

Safonov, M. M. (2008). Complete atlas of medicinal plants. Ternopil: Educational book Bogdan, 384 p.

Zhovtobryukh, N. V. (2004). Dependence of flowering duration of ornamental sunflowers grown in pots in closed soil on the diameter of the inflorescence. *Bulletin of Sumy National Agrarian University*, 12, 88-99.

Zhuykov, O. G., Ushkarenko, V. O., Burdiuh, O. O., Lavrenko, S. O. & Lavrenko, N. M. (2020). Photosynthetic activity and productivity of sunflower hybrids in organic and traditional cultivation technologies. *AgroLife Scientific Journal*, 9(1), 374-381.

***SSTU 4289:2004. (2004) Soil quality. Methods for determining organic matter. Kyiv: State Committee of Ukraine for Technical Regulation and Consumer Policy.

***SSTU 7863:2015. (2015). Soil quality. Determination of easily hydrolyzed nitrogen by the Cornfield method. Kyiv: State Committee of Ukraine for Technical Regulation and Consumer Policy.

***SSTU ISO 10390. (2007). Soil quality. Determination of pH. Kyiv: State Committee of Ukraine for Technical Regulation and Consumer Policy.

***SSTU ISO 11260:2001. (2001). Soil quality. Determination of cation exchange capacity and base saturation using barium chloride solution. Kyiv: State Committee of Ukraine for Technical Regulation and Consumer Policy.

***SSTU 4114:2002. (2002). Soils Determination of Mobile Compounds of Phosphorus and Potassium Using the Modified Machigina Method. Kyiv: State Committee of Ukraine for Technical Regulation and Consumer Policy.

***SSTU ISO 10693. (2001). Soil quality. Determination of carbonate content. Volume method. Kyiv: State Committee of Ukraine for Technical Regulation and Consumer Policy.