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EVALUATION OF SEED YIELD AND THOUSAND SEED WEIGHT OF CONFECTIONERY SUNFLOWER (*Helianthus annuus* L.) VARIETIES GROWN BY DIFFERENT FARMING TECHNIQUES IN THE NORTHERN STEPPE OF UKRAINE

Kateryna MAKLIAK, Maksym KORKODOLA

Plant Production Institute named after V.Ya. Yuriev of NAAS, 142, Heroiv Kharkova Ave., Kharkiv, Ukraine

Corresponding author email: emaklyak@gmail.com

Abstract

The paper presents data on the seed yield and thousand seed weight of confectionery sunflower (Helianthus annuus L.) varieties cultivated in the Northern Steppe of Ukraine. The study was conducted on three varieties-populations and one F1 hybrid. The study design included two types of basic tillage, three doses of fertilizer, and three plant densities. The seed yield significantly (P = 0.05) depended on the year of testing (the contribution of the year factor to the total variability was 38.88%), plant density (29.30%) and fertilizer dose (14.43%). It also depended on the tillage type (3.01%) and varietal characteristics (0.87%). The highest yield of seeds (up to 4.24 t/ha) was obtained with moldboard plowing, NPK fertilizer doses of 40:60:60 and 60:80:80 and plant density of 40,800 plants/ha. The thousand seed weight significantly (P=0.05) changed under the influence of the year of testing (32.11%), plant density (26.75%) and variety (25.92%), as well as under the influence of fertilization (3.24%) and tillage (3.75%). The largest thousand seed weight (up to 122.3 g) was obtained with moldboard plowing, NPK fertilizer doses of 40:60:60 and 60:80:80 and plant density of 20,400 plants/ha. Recommendations on the farming technique for confectionery sunflower have been drawn up.

Key words*: sunflower, confectionery, farming technique, seed yield, thousand seed weight, evaluation.*

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the most important oil crop in Ukraine. According to the State Statistics Service of Ukraine (SSSU), in the last six years, the annual harvested area of sunflower was not less than 6 million hectares (6.6 million hectares in 2021) (SSSU, 2022). As to the harvested area of sunflower, Ukraine ranks the second place in the world.

Confectionery sunflower occupies a rather large segment in Ukraine, up to 10% of the total area sown with the crop (Shyriaeva, 2015). Globally, confectionery sunflower production accounts for about 4% of total production (Pilorgé, 2020).

Weather risks pose a limiting factor in the confectionery sunflower production. In adverse weather conditions, there is a danger of growing sunflower seeds that would not meet the requirements for confectionery sunflower seed quality.

The Ukrainian climate allows harvesting high yields of confectionery sunflower, with a thousand seed weight of up to 150 g (Makliak et al., 2020). Confectionery sunflower attracts consumers' attention due to its high palatability and nutritional value (high contents of vitamins and minerals, high-quality protein source) (Joita-Pacureanu, 2018).

Despite the fact that the farming techniques for confectionery sunflower generally repeat those for oilseed sunflower, they have some peculiarities because of the need to ensure a high thousand seed weight and other indicators of confectionery raw materials. Adherence to these technological features becomes especially important in arid regions, since both the total yield and thousand seed weight decrease in sunflower suffering from water deficit (Ion et al., 2004; Pekcan et al., 2015).

Review of literature on elements of confectionery sunflower cultivation technologies made it possible to identify the main factors influencing commercially important indicators. Plant density influences greatly thousand seed weight. Crnobarac et al. (2014) noted that the thousand seed weight of a

confectionery genotype grown at a density of 70,000 plants/ha was about 50% lower than that of the same genotype grown at a density of 20,000 plants/ha. Turkish farmers sow confectionery sunflower according to the 50 cm × 100 cm pattern (Kaya, 2015), i.e. at a plant density of 20,000 plants/ha, allowing for a thousand seed weight of over 150 g. In addition, sparse sowing increases the yield of commercially important large seeds (Leonova et al., 2014). In the East Mediterranean Region of Turkey, Killi (2004) showed that a confectionery variety gave the maximum weight of thousand seeds at a plant density of 23,800 plants/ha. In China, confectionery sunflower varieties are sown with a density of 18,000-28,500 plants/ha or even 15,000 plants/ha (Feng et al., 2022).

Producers prefer genotypes capable of producing both high weights of thousand seeds and economically viable yield levels. Hladni et al. (2011) reported about confectionery sunflower hybrids producing both a high yield (4.18 t/ha) and a high thousand seed weight (101.2 g). This is disagreement with Killi's (2004) data, as he found that a confectionery variety grown at a density of 71,420 plants/ha gave the maximum yield, but at the same time, the minimum weight of thousand seeds.

To yield stably and high, sunflower requires large amounts of nutrients varying significantly depending on growing location and tillage type (Totckyi & Poliakov, 2009). The nitrogen demand of confectionery sunflower hybrids grown with various tillage types was studied by Schultz et al. (2018). With non-moldboard tillage, the nitrogen amount required to ensure the maximum yield was significantly reduced compared to traditional tillage (plowing). The mean yield of confectionery genotypes grown in non-moldboard tilled fields exceeded that of the genotypes grown in moldboard plowed fields. This contradicts the results of other researchers stating that sunflower requires autumn plowing (Terzić et al., 2017).

Nitrogen fertilization at doses of N_{60} and N_{120} positively affected both the seed yield of a confectionery sunflower variety and the thousand seed weight (Killi, 2004). At the same time, the difference between the effects of the tested doses of fertilizers on these characteristics was insignificant.

As to sowing timeframes, Killi and Altunbay (2005) showed that sowing time had almost the identical effects on the yields and thousand seed weights both in oilseed and in confectionery sunflower varieties; therefore, the authors recommended the same sowing timeframes for varieties of different uses.

Due to the lack of experimentally justified data on the complex influence of constituents of farming techniques on the yield and size of confectionery sunflower seeds, this paper is aimed to present the results on the seed yield and thousand seed weight of confectionary sunflower varieties studied under the dry conditions in the Northern Steppe of Ukraine.

MATERIALS AND METHODS

Experiment site and climate

The field trials were carried out in the experimental non-irrigated field in Balovka village (Dnipropetrovskyi District, Dnipropetrovska Oblast, Ukraine) in 2019-2021. The experimental plots were located 25 km northwest of Dnipro City, in the northern part of the steppe zone, on the left bank of the Dnipro River, at the latitude 48°37'03.1"N, longitude 34°48'17.3"E, 58 m above the sea level.

The study was carried out on typical chernozem with the following characteristics: humus content - 1.88%; pH of water extract - 6.68; pH of salt extract - 5.66; the content of labile nitrogen fractions - 3.45 mg/100 g of soil; the content of labile phosphorus fractions - 20.5 mg/100 g of soil; the content of labile potassium fractions - 20.1 mg/100 g of soil; the content of labile sulfur fractions - 4.1 mg/100 g of soil.

According to the data of the Ukrainian Hydrometeorological Center (UHC), the climate of the test zone is temperate continental, with hot and rather dry summers. The average annual air temperature is 9ºC; the average annual rainfall is 539 mm (UHC, 2022). The sunflower growing periods in the study years were as follows: 2019 was relatively hot with normal wetting; 2020 was relatively hot and dry; 2021 was relatively cool and waterlogged. The main meteorological indexes during sunflower vegetation in the experiments are given in Table 1.

Table 1. Meteorological indexes during sunflower vegetation in the field experiments

Months	2019		2020		2021		Long-term data	
	AT, ºC	RA, mm	AT, ºC	RA, mm	AT, ºC	RA, mm	AT, ºC	RA, mm
April	11.2	32.3	8.9	11.5	8.0	53.5	9.4	12.0
May	17.9	48.3	13.8	38.1	15.8	27.0	16.0	46.0
June	24.0	30.6	21.7	38.5	19.5	202.3	19.6	59.0
July	21.5	59.2	23.5	20.4	23.6	69.4	21.3	56.0
August	21.2	57.5	22.0	11.9	22.8	51.4	20.6	37.0
September	16.3	19.8	19.4	32.1	13.8	23.5	15.4	36.0
Average	18.7	–	18.2	–	17.3	–	17.1	
Total	–	247.7	–	152.5	–	427.1	–	246.0

Note: AT - air temperature; RA - rainfall amount.

Plant material

Four confectionery sunflower genotypes were investigated: three genotypes were varieties-populations (SPK, Belochka [originator - All-Russian Research Institute of Oil Crops, RF] and Zaporizhskyi Kondyterskyi [originator - Institute of Oilseed Crops of NAAS, Ukraine]) and one F1 hybrid (Hudvin [originator - Plant Production Institute named after VYa Yuriev of NAAS, Ukraine]).

These genotypes are successfully grown in the region to produce seeds for the confectionery industry.

Sunflower variety SPK. A large-fruited variety-population of mid-ripening sunflower. The thousand seed weight amounts to 150 g at a plant density of ≤ 30,000 plants/ha. The oil content in seeds amounts to 48.5%. The seed yield can be up to 3.9 t/ha. The plant height is ≤ 210 cm. The variety is susceptible to rust, downy mildew and broomrape.

Sunflower variety Belochka. A large-fruited variety-population of short-season sunflower. The thousand seed weight amounts to 100 g at a plant density of ≤ 40,000 plants/ha. The oil content in seeds amounts to 53.0%. The seed yield can be up to 4.1 t/ha. The plant height is 170–180 cm. The variety is noticeable for uniform plant height as well as for anthesis and ripening periods. It is resistant to several broomrape races and downy mildew.

Sunflower variety Zaporizhskyi Kondyterskyi. A large-fruited variety-population of mid-ripening sunflower. The thousand seed weight amounts to 125 g at a plant density of ≤ 30,000 plants/ha. The oil content in seeds amounts to 44.4%. The seed yield can be up to 4 t/ha. The plant height is ≤ 250 cm. The variety is resistant to several broomrape races and downy mildew.

Sunflower hybrid Hudvin. Simple interline mid-ripening hybrid. The thousand seed weight amounts to 135 g at a plant density of 28,000–30,000 plants/ha. The oil content in seeds amounts to 51%. The seed yield can be up to 4.2 t/ha. The plant height is ≤ 180 cm. In the field, it is highly resistant to broomrape, rust and downy mildew. The hybrid boasts excellent palatability.

Experiment design

The experiments were conducted during three crop seasons: 2019, 2020 and 2021.

The sunflower farming techniques in the experiments were based on the conventional recommendations for the crop cultivation in the South of Ukraine. Spring wheat was the forecrop. Plants were sown during the first 10 days of May. Weeds in the field were effectively eradicated mechanically.

The field experiments were conducted in three replications using split plot design.

The study was focused on evaluation of the following constituents of the cultivation technology:

Factor A - basic tillage. The experiment included two types: traditional moldboard plowing - tandem disking of stubble, moldboard plowing to a depth of 22–25 cm; non-moldboard tillage - tandem disking of stubble, non-moldboard tillage to a depth of 25-27 cm.

Factor B - fertilization. The experiment included three fertilizer doses: NPK 20:40:40, 40:60:60 and 60:80:80. Fertilization was combined with basic tillage.

Factor C - plant density. The experiment included three graduations of the plant density: 20,400 plants/ha, 31,700 plants/ha and 40,800 plants/ha, with a row spacing of 70 cm,

90 cm and 70 cm and a distance between plants 70 cm, 35 cm and 35 cm, respectively.
Thus, there were 216 experimental plots. The area of each plot was 11.55 m^2. Seeds were sown in four rows. The first and fourth rows served as protection and two inner rows were used for analysis. The seed yield was measured after harvesting two inner rows.

Measured parameters
The measured parameters were the seed yield and thousand seed weight. To measure the seed yield, all plants in the plot were cut and threshed manually. Then seeds were cleaned of impurities and weighed. The weight of seeds from the plot was normalized to standard moisture content (10%) and recalculated in t/ha.
To determine the thousand seed weight, an average sample was taken from the yield of each plot; two working samples of 500 seeds were taken from the average sample, weighed separately, and recalculated as thousand seed weight expressed in grams.

Statistical analysis
Statistical parameters (arithmetic mean, standard error [$\bar{x}\pm s$], coefficient of variation [Cv] and pair correlation coefficient [r]) were calculated in Statistica 8.0 (Stat Soft. Inc.), as Dospekhov described (1985). According to the applied method for assessing the coefficient of variation, a trait is considered slightly varying if Cv is less than 10%, moderately varying if $10\% \leq Cv \leq 20\%$ and highly variable if Cv is greater than 20%. The significance of the correlation coefficient r was determined at the P=0.05 level. Analysis of variance (ANOVA) was used to determine the significance of differences between the experimental variants. The difference was considered significant when the F-test indicated statistical significance at the $P<0.05$ level.

RESULTS AND DISCUSSIONS

Seed yield. The seed yield of the confectionery sunflower genotypes significantly depended on all the main factors in the experiments. The year of testing influenced the yield to the greatest extent (the contribution of this factor to the total variability was 38.88%) (Table 2), confirming strong dependence of sunflower yield on weather conditions, which was frequently reported in literature, and the need to select adapted genotypes (Škorić, 2012). In addition, the yield changed significantly under the influence of plant density (29.30%) and fertilizer dose (14.43%).
To a lesser extent, but also significantly, the yield was affected by tillage type (3.01%) and varietal characteristics (0.87%). As for the interaction between the factors, the 'fertilizer - plant density' interaction (B×C) accounted for 0.38%; the 'plant density – testing year' interaction (C×E) - 0.28%; and 'variety - testing year' interaction (D×E) - 1.19%. The contributions of other inter-factor interactions to the total variability were insignificant.

Table 2. Statistical assessment of the effects of the farming practices on the yields of the confectionery sunflower genotypes in 2019-2021

Factor, interaction between factors	Contribution of the factor to the total variability, %	F_{test}
Tillage (A)	3.01	131.78*
Fertilization (B)	14.43	315.90*
Plant density (C)	29.30	641.50*
Genotype (D)	0.87	12.75*
Year (E)	38.88	851.17*
B×C	0.38	4.11*
C×E	0.28	3.04*
D×E	1.19	8.68*
Others	11.66	ns

*Significant at P<0.05
ns = not significant

Thus, in the studied set of genotypes, the inter-year variability of the mean yield exceeded the inter-variety variability. In other words, the genotypes yielded similarly to the weather conditions. The plant density and fertilizer dose are technological approaches that can significantly affect the yields of the confectionery sunflower genotypes under investigation. This is consistent with other researchers' conclusions. For example, Balalić et al. (2016) found that the yield of confectionery hybrids, in addition to the potential of the hybrid itself, was significantly affected by plant density and the 'hybrid - density' interaction.
Our data confirmed the positive effect of mineral fertilizers on the confectionery sunflower yield demonstrated by other authors

(Schultz et al., 2018; Li et al., 2018). The mean yield vs. gradations of the experimental factors indicates the direction of the trait variability. Here, with moldboard plowing, as the fertilizers amount was increased, the yield rose from 2.65±0.085 t/ha at an NPK dose of 20:40:40 to 3.14±0.099 t/ha at 40:60:60 and 3.26±0.101 t/ha at 60:80:80 (Table 3). Upon non-moldboard tillage, the yield increased from 2.46±0.080 t/ha at an NPK dose of 20:40:40 to 2.90±0.096 t/ha at 40:60:60 and 2.99±0.093 t/ha at 60:80:80.

Taking into account the standard errors for moldboard plowing, there was a significant gain in the yield at an NPK dose of 40:60:60 in comparison with the yield at 20:40:40. There was no significant rise in the yield at an NPK dose of 60:80:80 in comparison with the yield at 40:60:60. A similar trend was observed for non-moldboard tillage.

Table 3. Expression and variation ranges of the seed yields in the confectionary sunflower genotypes in 2019-2021, t/ha

Factor, experimental variant	Moldboard plowing				Non-moldboard tillage			
	$\bar{x}\pm s$	min	max	Cv, %	$\bar{x}\pm s$	min	max	Cv, %
Fertilization, NPK								
20:40:40	2.65±0.085	1.58	3.47	19.3	2.46±0.080	1.42	3.44	19.5
40:60:60	3.14±0.099	1.88	4.22	18.9	2.90±0.096	1.69	3.97	19.9
60:80:80	3.26±0.101	1.97	4.24	17.8	2.99±0.093	1.76	3.91	18.7
Plant density, plants/ha								
20,400	2.53±0.078	1.58	3.34	18.4	2.31±0.069	1.42	3.02	17.9
31,700	3.13±0.085	2.11	2.93	16.2	2.88±0.078	1.93	3.63	16.2
40,800	3.34±0.093	2.26	4.24	16.7	3.15±0.088	2.08	3.97	16.7
Genotypes								
SPK	2.99±0.104	1.88	3.88	18.1	2.81±0.105	1.72	3.87	19.4
Belochka	2.91±0.119	1.72	4.09	21.2	2.74±0.109	1.69	3.91	20.7
Zap. Kond.	3.11±0.116	1.96	4.24	19.3	2.86±0.112	1.68	3.97	20.3
Hudvin	3.00±0.135	1.58	4.22	23.5	2.71±0.126	1.42	3.78	24.2
Year								
2019	3.09±0.080	2.12	3.84	15.6	2.62±0.080	2.01	3.16	13.7
2020	2.46±0.068	1.58	3.14	16.5	2.28±0.066	1.42	2.92	17.5
2021	3.46±0.079	2.35	4.24	13.7	3.20±0.078	2.31	3.97	14.7
Total	3.00±0.059	1.58	4.24	20.4	2.78±0.056	1.42	3.97	21.0

The yield ranged, depending on fertilizer dosing, from 1.58 t/ha (NPK 20:40:40) to 4.24 t/ha (NPK 60:80:80) with moldboard plowing and from 1.42 t/ha (NPK 20:40:40) to 3.97 t/ha (NPK 40:60:60) with non-moldboard tillage.

To achieve the maximum yield, it is sufficient to apply NPK fertilizers at a dose of 40:60:60, which will make it possible to obtain a seed yield of up to 4.22 t/ha with moldboard plowing and up to 3.97 t/ha with non-moldboard tillage.

As the plant density was increased, the yield rose: with moldboard plowing, the yield was raised from 2.53±0.078 t/ha at a density of 20,400 plants/ha to 3.13±0.085 t/ha at 31,700 plants/ha and to 3.34±0.093 t/ha at 40,800 plants/ha; upon non-moldboard tillage, the yield was boosted from 2.46±0.080 t/ha at a density of 20,400 plants/ha to 2.88±0.078 ha at 31,700 plants/ha and to 2.99±0.093 at 40,800 plants/ha.

Taking into account the standard errors for moldboard plowing, the gain in the yield was significant at each density increment. As to non-moldboard tillage, the gain was significant when the density was increased to 31,700 plants/ha.

The yield ranged (minimum - maximum), depending on plant density, from 1.58 t/ha (20,400 plants/ha) to 4.24 t/ha (40,800 plants/ha) with moldboard plowing and from 1.42 t/ha (20,400 plants/ha) to 3.97 t/ha (40,800 plants/ha) with non-moldboard tillage.

Thus, to achieve the maximum yield, it is necessary to sow the confectionery varieties at a density of 40,800 plants/ha, which will make it possible to obtain a yield of up to 4.24 t/ha with moldboard plowing and up to 3.97 t/ha with non-moldboard tillage.

The highest mean value of the yield with moldboard plowing was recorded for Zaporizhskyi Kondyterskyi (3.11±0.116 t/ha); the lowest - for Belochka (2.91±0.119 t/ha). With non-moldboard tillage, the highest mean yield was harvested from Zaporizhskyi Kondyterskyi (2.86±0.112 t/ha) and the lowest - from Hudvin (2.71±0.126 t/ha). However, given the standard errors, the difference between the yields of the genotypes was not significant.

The studied genotypes potentially have great seed yields. The maximum yield with moldboard plowing was harvested from Zaporizhskyi Kondyterskyi (4.24 t/ha) Hudvin (4.22 t/ha). The maximum yield with non-moldboard tillage was recorded for Zaporizhskyi Kondyterskyi (3.97 t/ha) and Belochka (3.91 t/ha).

There were significant inter-year variations in the mean value of the seed yield. With moldboard plowing, the highest mean yield was recorded in 2021 (3.46±0.079 t/ha); the lowest - in 2020 (2.46±0.068 t/ha). With non-moldboard tillage, the mean yield was 3.20±0.078 t/ha in 2021 and 2.28±0.066 t/ha in 2020. Thus, the sunflower confectionery genotypes produced the maximum yields in the year when the weather in the test location was relatively cool and excessively humid.

The values of the coefficient of variation Cv showed that the yield variability in most of the experimental variants was moderate. The yield variability was high in variety Belochka and hybrid Hudvin grown with moldboard plowing. With non-moldboard tillage, the yield variability was high in varieties Belochka and Zaporizhskyi Kondyterskyi as well as in hybrid Hudvin. In general, the seed yield of the confectionery sunflower varieties and hybrids grown with moldboard plowing (3.00±0.059 t/ha) was higher than that with non-moldboard tillage (2.78±0.056 t/ha), i.e. the difference was 0.22 t/ha.

Thousand seed weight. The thousand seed weight of the confectionery sunflower genotypes significantly depended on all the main experimental factors. The thousand seed weight was affected by testing year to the greatest extent (the contribution of this factor to the total variability was 32.11%), plant density (26.75%) and variety (25.92%) (Table 4). To a lesser extent, but also significantly, the thousand seed weight was affected by fertilization (3.24%) and tillage (3.75%).

As for the interaction between factors, the 'tillage - fertilization' interaction of (A×B) accounted for 0.18% of the total variability; the 'tillage - plant density' interaction (A×C) - for 0.68%; the 'tillage - variety' interaction (A×D) - for 0.21%; the 'plant density - variety' interaction (C×D) - for 0.41%; the 'plant density - testing year' interaction (C×E) - for 0.28%; the 'variety - testing year' interaction (D×E) - for 1.19%; and the 'tillage - plant density - variety' interaction (A×C×D) (three-factor interaction) - for 0.36%. The contributions of other factor interactions to the total variability were insignificant.

Table 4. Statistical assessment of the effects of the farming practices on the yields of the confectionery sunflower genotypes in 2019-2021

Factor, interaction of factors	Contribution of the factor to the total variability, %	F_{test}
Tillage (A)	3.24	298.21*
Fertilization (B)	3.75	172.52*
Plant density (C)	26.75	1230.55*
Genotype (D)	25.92	794.85*
Year (E)	32.11	1476.9*
A×B	0.18	8.09*
A×C	0.68	31.07*
A×D	0.21	6.51*
C×D	0.41	6.30*
C×E	0.31	7.02*
D×E	0.33	5.02*
A×C×D	0.36	5.58*
Others	5.75	ns

* Significant at P<0.05
ns = not significant

Based on the percentage contribution of each of the studied experimental factors to the total variability of the trait, the plant density and genotype selection can be recognized as farming practices that can significantly affect the thousand seed weight. The fertilization effect was noticeably smaller.

The mean value of the thousand seed weight vs. gradations of the experimental factors indicates the direction of the trait variability. Here, as the fertilizer amount was increased with moldboard plowing, the thousand seed weight became greater: from 93.3±1.64 g at an NPK dose of 20:40:40 to 98.1±1.73 g at 40:60:60 and to 99.3±1.65 g at 60:80:80

(Table 5). With non-moldboard tillage, the mean weight of thousand seeds was raised from 90.5±1.79 g at an NPK dose of 20:40:40 to 94.0±1.84 g at 40:60:60 and to 94.2±1.87 g at 60:80:80.

Taking into account the standard errors for moldboard plowing, there was a significant rise in the thousand seed weight at an NPK dose of 40:60:60 in comparison with that at 20:40:40. There was no significant gain in the thousand seed weight at an NPK dose of 60:80:80 in comparison with that at 40:60:60. A similar trend was observed for non-moldboard tillage.

Table 5. Expression and variation ranges of the thousand seed weight in the confectionary sunflower genotypes in 2019-2021, g

Factor, experimental variant	Moldboard plowing				Non-moldboard tillage			
	$\bar{x}$±s	min	max	Cv, %	$\bar{x}$±s	min	max	Cv, %
Fertilization, NPK								
20:40:40	93.3±1.64	74.3	116.3	10.5	90.5±1.79	65.1	113.9	11.9
40:60:60	98.1±1.73	75.3	122.3	10.6	94.0±1.84	70.0	115.6	11.8
60:80:80	99.3±1.65	80.2	121.9	10.0	94.2±1.87	67.1	118.3	11.9
Plant density, plants/ha								
20,400	102.2±1.56	85.3	122.3	9.2	98.3±1.56	84.7	118.3	9.5
31,700	98.3±1.49	82.0	116.4	9.1	96.5±1.33	82.8	113.3	8.2
40,800	90.1±1.46	74.3	106.2	9.8	83.8±1.61	65.1	102.4	11.5
Genotypes								
SPK	103.2±1.86	87.1	122.3	9.4	99.5±1.86	81.5	118.3	9.7
Belochka	99.1±1.60	85.4	114.4	8.4	96.7±1.72	82.5	113.3	9.2
Zap. Kond.	96.7±1.68	81.5	114.0	9.0	91.5±1.78	75.1	107.4	10.1
Hudvin	88.5±1.68	74.3	106.9	9.8	83.9±1.89	65.1	99.3	11.7
Year								
2019	92.9±1.32	75.0	108.7	8.5	89.3±1.47	68.4	103.9	9.9
2020	91.8±1.29	74.3	103.7	8.5	87.9±1.48	65.1	100.9	10.1
2021	105.9±1.43	85.8	122.3	8.1	102.4±2.15	80.1	115.6	9.4
Total	96.9±0.99	74.3	122.3	10.6	92.9±1.06	65.1	118.3	11.9

The thousand seed weight ranged, depending on fertilizer dosing, from 74.3 g (NPK 20:40:40) to 121.9 g (NPK 60:80:80) with moldboard plowing and from 65.1 g (NPK 20:40:40) to 118.3 g (NPK 60:80:80) with non-moldboard tillage. To achieve the maximum value of the thousand seed weight, it is sufficient to apply NPK fertilizer at a dose of 40:60:60. In the experiment, this allowed us to obtain the thousand seed weight of up to 122.3 g with moldboard plowing and of up to 115.6 g with non-moldboard tillage.

With an increase in the plant density upon moldboard plowing, the thousand seed weight decreased: from 102.2±1.56 g at a density of 20,400 plants/ha to 98.3±1.49 g at 31,700 plants/ha and to 90.1±1.46 g at 40,800 plants/ha. When the plant density was increased upon non-moldboard tillage, the thousand seed weight declined: from 98.3±1.56 g at a density of 20,400 plants/ha to 96.5±1.33 g at 31,700 plants/ha and to 83.8±1.61 g at 40,800 plants/ha.

Taking into account the standard errors, there was a significant reduction in the thousand seed weight with each increment to the plant density, both with moldboard plowing and non-moldboard tillage.

The thousand seed weight varied (minimum - maximum), depending on the plant density, from 74.3 g (40,800 plants/ha) to 122.3 g (20,400 plants/ha) with moldboard plowing and from 65.1 g (40,800 plants/ha) to 118.3 g (20,400 plants/ha) with non-moldboard tillage.

Thus, to achieve the maximum value of the thousand seed weight, it is advisable to sow the confectionery varieties at a density of 20,400 plants/ha. This will allow for the thousand seed weight of up to 122.3 g with moldboard plowing and of up to 118.3 g with non-moldboard tillage.

The highest mean value of the thousand seed weight upon moldboard plowing was recorded for SPK (103.2±1.86 g) followed by Belochka

(99.1±1.60 g) and Zaporizhskyi Kondyterskyi (96.7±1.68 g), while the lowest value of the thousand seed weight was noticed for Hudvin (88.5±1.68 g). Upon non-moldboard tillage, the highest mean value of the thousand seed weight was observed in SPK (99.5±1.86 g) and Belochka (96.7±1.72 g) followed by Zaporizhskyi Kondyterskyi (91.5±1.78), while the lowest value of the thousand seed weight was recorded for Hudvin (83.9 ±1.89 g).

The studied genotypes have a great potential for the thousand seed weight. The maximum weight of thousand seeds was recorded for SPK grown with moldboard plowing and non-moldboard tillage: 122.3 and 118.3 g, respectively.

The mean value of the thousand seed weight differed significantly from year to year. Upon moldboard plowing, the highest mean value of the thousand seed weight was recorded in 2021 (105.9±1.43 g) and the lowest – in 2019 (92.9±1.32 g) and 2020 (91.8±1.29 g). Upon non-moldboard tillage, the mean value of the thousand seed weight was 102.4±2.15 g in 2021 and 87.9±1.48 g in 2020. Thus, the weather-dependent variability pattern for the thousand seed weight went in parallel with that for the seed yield.

The values of the coefficient of variation Cv showed that the thousand seed weight varied slightly in most experimental variants.

In general, the thousand seed weight of the confectionery sunflower varieties and hybrids grown with moldboard plowing (96.9±0.99 g) was higher than that with non-moldboard tillage (92.9±1.06), i.e. the difference was 4 g.

'Yield - thousand seed weight' relationship. Paired correlation coefficients between the studied parameters were calculated separately for moldboard plowing and non-moldboard tillage. The correlation coefficient was 0.205 for moldboard plowing and 0.101 for non-moldboard tillage and did not reach statistical significance at the P=0.05 level. This is in disagreement with reports about a positive correlation between sunflower yield and thousand seed weight (Mijić et al., 2009; Hladni et al., 2010; Sincik & Goksoy, 2014; Koutroubas & Christos, 2020).

Consequently, the seed yield of confectionery sunflower genotypes was determined not only by thousand seed weight, but also by other yield constituents, for example by seed weight per head. When choosing a variety for cultivation for confectionery purposes, one should bear in mind that its high weight of thousand seeds is not always associated with a high yield.

CONCLUSIONS

The study confirmed the high potential of confectionery sunflower in terms of yield and thousand seed weight in the Northern Steppe of Ukraine. With moldboard plowing, variety Zaporizhskyi Kondyterskyi and hybrid Hudvin yielded 4.24 t/ha and 4.22 t/ha, respectively. The thousand seed weight was 122.3 g and 118.3 g in variety SPK grown with moldboard plowing and non-moldboard tillage, respectively.

The seed yield was most influenced by testing year, plant density and fertilizer dosing. The thousand seed weight was most influenced by testing year, plant density and genotype. The yield and thousand seed weight in the moldboard experiment exceeded those in the non-moldboard one. The mean difference was 0.22 t/ha and 4 g, respectively.

There was no significant correlation between yield and thousand seed weight.

To achieve a high weight of thousand seeds, it is recommended to sow confectionery sunflower varieties with moldboard plowing, a plant density of 20,400 plants/ha and an NPK fertilizer dose of 40:60:60. These farming practices will allow for thousand seed weight of up to 122.3 g with moldboard plowing and of up to 118.3 g with non-moldboard tillage. To achieve the maximum yield, it is recommended to sow sunflower varieties with moldboard plowing, a plant density of 40,800 plants/ha and an NPK fertilizer dose of 40:60:60. This will allow for seed yields of up to 4.22 t/ha with moldboard plowing and of up to 3.97 t/ha with non-moldboard tillage. Under such conditions, the thousand seed weight will not exceed 106.2 g with moldboard plowing or 102.4 g with non-moldboard tillage.

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