Olha Andriienko, Kateryna Vasylkovska*, Andrii Andriienko, Oleksii Vasylkovskyi, Mykola Mostipan and Larysa Salo

Response of sunflower hybrids to crop density in the steppe of Ukraine

https://doi.org/10.1515/helia-2020-0011
Received May 18, 2020; accepted July 6, 2020; published online August 3, 2020

Abstract: Field studies conducted in 2018–2019 in the northern Steppe of Ukraine with sunflower hybrids of different maturity groups (LG 50300, LG 5580, LG 5478, LG 5638, LG 5662) showed that the crop density of early-crop hybrid LG 50300 from 55,000 plants/hectare to 70,000 plants/hectare led to a decrease in productivity by 0.11 t ha^{-1} and a decrease in oil content by 0.9%. The density of middle-early hybrid LG 5580 resulted in a decrease in sowing productivity of 0.21 t ha^{-1}, while oil content remained nearly the same. Another middle-early hybrid LG 5478 showed slight variations in productivity and oil content with an increase of crop density. The study of the mid-season hybrid LG 5038 showed a decrease in sowing productivity by 0.2 t ha^{-1} with the density up to 70,000 plants/hectare. Mid-season hybrid LG 5662 with density of 70,000 plants/hectare showed productivity increase by 0.14 t ha^{-1}.

Keywords: crop density; oil content; sunflower; productivity; plant diseases.

Introduction

Sunflower is one of the priority crops among agrarians in view of its productivity and profitability. On average, 20–23% of all acreage of Ukraine is allocated for sunflower. This crop is the key to the financial stability of most farms (Khmarskyi 2017; Nahornyi 2001; Semerci 2012).

***Corresponding author: Kateryna Vasylkovska**, Central Ukrainian National Technical University (CUNTU), Kropyvnytskyi, 25006, Ukraine, Phone: +380667103625, E-mail: vasilkovskakv@ukr.net
Olha Andriienko, Oleksii Vasylkovskyi, Mykola Mostipan and Larysa Salo
Central Ukrainian National Technical University (CUNTU), Kropyvnytskyi, 25006, Ukraine
Andrii Andriienko: Limagrain Ukraine LLC, Kyiv, 04053, Ukraine

The geographical distribution of sunflower cultivation has changed significantly due to the changes in weather conditions and creation of plastic early-season hybrids. Previously, the Steppe was considered a traditional area of sunflower production. In the last decade the areas of sunflower cultivation in several forest-steppe regions have increased several times (Nedealcov et al. 2017).

To express the genetic productive capacity of sunflower, it is necessary to create most favourable conditions for the growth and development of plants, that is, to provide seeds with necessary area of nutrition, so that the sprout has its habitat for better development (Mostipan et al. 2017; Vasylkovska et al. 2016). The optimal number of plants per unit area and the uniformity of their distribution is the main technological requirement for the formation of optimal yield.

The use of moisture, light, and intensity of the assimilation process of sunflower crop formation correlate with plant density and productivity (Ibrahim 2012; Tkalich et al. 2011, pp. 116–119). Therefore, plant density is an important element of sunflower growing technology. As a result of optimal determining of the number of plants per unit area, maximum yield can be achieved while maintaining high quality indicators (Khmarskyi 2017; Onopriienko 1998).

For different soil and climatic conditions, plant density is considered optimal if the plants get rational use of moisture, soil nutrients and the fullest use of solar energy (Koshkin et al. 2005; Lisovyi 2002; Korytnyk et al. 2001; Minkovskyi 2000; Oleksiuk 2000). Both excessive plant densification and thinness are known to result in a significant decrease in productivity and quality (Lykhochvor 2004; Hrabovskyi 2010).

Many years of research by academician V. Pustovoit (Tkalich et al. 2011, pp. 116) indicate that the highest sunflower productivity can be achieved at the plant density of 50 thousand/hectare (row spacing of 70 cm), which corresponds to the nutrition area of one plant about 2000 cm^2. The conclusion of the above studies is to establish the behaviour of sunflower: the longer is the vegetation period of varieties or hybrids, the greater (with other things being equal)the area of nutrition and the higher its productivity is; the shorter is the growing season, the greater the plant density per unit area may be.

Smaller heads are formed in the higher density, causing productivity reduction by 0.2–0.3 t ha^{-1}, and there are weeds in the thinned areas, which also results in reduced productivity (Harbar et al. 2017; Minkovskyi 2000). The standard row spacing is 70 cm, but the area of plant nutrition is far from optimal. Moreover, this behaviour is observed for different rows spacing with different numbers of plants in a row, both in row and square-pocket planting.

Plant density in the areas with the highest sunflower productivity in Ukraine decreases in the direction from northwest to southeast. Thus, in the experiments of the research institutions, the highest sunflower productivity in the eastern forest-steppe was obtained at the crop density of 51,000 plants/hectare (Budennyi et al. 1987; Tkalich et al. 2011, pp. 116–117). At the same time, in the semi-arid south of Ukraine, it is necessary to grow fewer plants per hectare in order to obtain high sunflower crop than in the regions of central and northern steppes. The density of plants depends directly on the conditions of water supply (Tkalich et al. 2011, pp. 118–119).

At optimal plant densities, narrowing the row spacing from 70 to 45 cm in some cases led to increased productivity (Harbar et al. 2017; Minkovskyi 2000). At the row spacing of 70 cm, increasing crop density of varieties and hybrids from 40–50,000 to 60–70,000 plants/hectare led to a decrease in productivity. At a row spacing of 45 cm, the productivity of the varieties decreased even more, while the productivity of hybrids slightly increased (Tkalich et al. 2011).

In the areas where moisture is a limiting factor, crop density depends primarily on the moisture content, the higher it is, the larger is the number of plants per unit area. In conditions of the Steppe with its lack of water and when the crops are denser than normal, even the application of increased doses of fertilizers does not give effect (Diakov 1984).

In the case of excessive plant density, which is often sought by farmers, due to the worse ventilation conditions, a favourable microclimate for the development of fungal diseases, including white and gray rot, is created (Budennyi et al. 1987; Diakov 1984; Tkalich et al. 2011).

When studying the response of different hybrids to the increase in crop density in the conditions of the steppe and forest-steppe zones of Ukraine, it was found that the density of 45,000 plants/hectare is better for mid-season hybrids. For hybrids with short growing season, the recommended density is increased by 20–25% in sufficient moistening conditions and is reduced by 10–15% in insufficient moistening conditions. (Orlov 2013, p. 127; Spitzer et al. 2018).

In crops with high density there is a larger consumption of moisture reserves before the onset of the generative period. When plants are evenly placed on the square, their mutual suppression begins later. It has been found that in denser crops the mutual suppression of plants begins to affect adversely the formation of vegetative mass of agrocenosis, starting with the budding phase (Lykhochvor 2004; Harbar et al. 2017).

Kirovohrad region (Ukraine) is the zone of insufficient moisture content, so it is important to know what agrotechnical practices allow to make more rational use of basic factors of plant life and above all moisture.

Thus, the choice of optimal crop density of different sunflower hybrids and the influence of these factors on the productivity and oil content in specific soil and climatic conditions is an essential, promising and important task.

Material and methods

Field experiments were conducted during 2018–2019 at the demonstration site of the subsidiary agricultural enterprise “Likarivka 2” (Oleksandria district, Kirovohrad region, Ukraine). The experimental site is located in the northern steppe of Ukraine. The climate is temperate continental, which is characterized by insufficient humidity with uneven rainfall throughout the year. The soil type was chernozem with usual medium humus deep, heavy loamy medium – washed down, which becomes lumped from the depth of 45–55 cm. Soil absorption complex is saturated with bases of calcium and magnesium in the ratio of 5:1. Reaction of soil solution is neutral pH 6.5–7.0, total depth of humus is about 65 cm thick. In the plow layer humus content is 4.0–4.2%, the content of the main nutrients (according to Chirikov) is: hydrolyzing nitrogen – 10.5 mg/100 g, moving phosphorus –10.4 mg/100 g, exchangeable potassium – 11.2 mg/100 g of soil (DSTU 4115-2002). That is, soil on the site has average fertility rates.

The years of research were significantly different by their hydrothermal conditions. The rainfall during sunflower growing season was 291 mm in 2018 and 178 mm in 2019. Accordingly, the hydrothermal coefficients, calculated by H. Selyaninov’s methodology, were 1.1 and 0.9, which indicates dry conditions in 2019 and their negative impact on the productivity level.

The number of variants in the experiment was 10, with three replications, so total number of plots was 30. Sown area of each plot was 840 m^2 and the harvesting area was 560 m^2. The experiment design was of split plots, where the main plots were four hybrids and the subplots were two sowing rates. The studies were performed with the following sunflower hybrids: early LG 50300; middle-early LG 5580 and LG 5478; mid-season LG 5638 and LG 5662. All of them belong to the selection of Limagrain (Groupe Limagrain Holding S.A.). Each of hybrids sown at two densities: of 55,000 and 70,000 plants per hectare. The technology of sunflower cultivation in the experiment is generally accepted for this soil and climate zone. The experiments were carried out in a field short rotation of crops in a chain of winter wheat – corn – sunflower, after the fore-crop maize for grain. After harvesting the fore-crop, the field was peeled by the disc harrow (the depth of tillage is 6–8 cm) and the stubble was disked with a disc harrow (10–12 cm), the plowing was done with a plow with a pre-plow (25–27 cm). Early spring harrowing and pre-sowing cultivation were conducted in spring. Sowing took place at the optimal time for the Northern Steppe zone (warming of soil at the depth of seed placing to 10–12 °C) and was on 25-th and 28-th of April in 2018 and 2019 respectively. During sowing, fertilizers were used (24 kg/hectare of NPK active ingredient). For sowing we used certified seeds, with laboratory germination of 92–94%, purity of 98%, weight of 1000 seeds of 65–80 g, moisture content of 7%. The seeds were treated with Cruiser 322 FS. Weeds were sprayed with Prymextra TZ Gold 500 SC herbicide (4.5 l/hectare) after sowing. Crop care included rolling and inter-row cultivation as needed. Pest control was conducted under conditions of exceeding the economic threshold with Nurelle D 550 EC in the rate of 1.0 l/hectare.

Checking for sunflower plant diseases, as well as the infection of crops by broomrape (*Orobanche Cumana*), was carried out at the beginning of sunflower blossoming by inspecting a plot of 20 plants that are equally spaced from each other. Harvesting was carried out from all plants at 560 m^2 of each plot at three replication by a combine harvester. The harvesting period was defined by the harvest maturity, i.e. 85% of plants’ heads had brown rear side, while the rest had yellow or yellow-brown rear side of heads. This corresponds to seed moisture of 7–12% (Tkalich et al. 2011, pp. 163–165). Seed moisture was determined immediately before the harvest, by selecting plant head and subsequently determining the moisture content of sunflower seeds in the laboratory. The identification of oil content was carried out by the Soxtlet method of de-oiled residue, which is the extraction of the oil with ethyl ether (DSTU 7577-2014).

Results and discussion

Growth and development of sunflower hybrids

In the course of long evolution sunflower has acquired typical plant properties for the steppe zone, adapted to the transfer of temperature fluctuations in different periods of development, to air and soil drought. It has high environmental plasticity for growth in large areas of the Steppe and Forest-Steppe of Ukraine.

Sunflower flowers are collected in inflorescences called head. The shape of the head can be curved, flat and convex.

Table 1 shows the diameter of the head during flowering. It should be noted that the plants of all the studied sunflower hybrids reduced the diameter of the head by sowing to 70,000 plants/hectare.

As we can see, the average diameter of heads in different hybrids during the flowering years fluctuated from 22.7 to 25.8 cm at the density of 55,000 plants/hectare. At the same time, this indicator for growing hybrids with the density of 70,000 plants/hectare ranged from 21.1 to 24.2 cm.

The hybrid LG 50300 had the smallest diameter of head at flowering period (21.1 cm) at the crop density of 70,000 plants/hectare and 22.7 cm at 55,000 plants/hectare. The highest figures were recorded in the hybrid LG 5635 with

Table 1: Head diameter and plant height of sunflower hybrids during flowering.

Hybrid	Density of crop (1000 plant per hectare)	Head diameter (cm)	Height of plants (cm)
LG 50300	55	22.7	156.5
	70	21.1	160.0
LG 5580	55	24.9	173.5
	70	23.7	177.5
LG 5478	55	25.8	175.5
	70	23.8	180.0
LG 5638	55	25.8	177.0
	70	23.4	181.5
LG 5662	55	25.5	162.5
	70	24.2	166.5

25.8 cm at the crop density of 55,000 plants/hectare and 23.8 cm in higher density crops.

The reduction in head diameter on the higher density variants of LG 50300 hybrid was 1.6 cm, LG 5580 hybrid – 1.2 cm, LG 5478 – 2.0 cm, LG 5638 – 2.4 cm and LG 5662 – 1.3 cm. Therefore, with the higher density of crops, the diameters of heads of LG 5478 and LG 5638 hybrids maximally changed.

On average, for two years of research at flowering phase, the height of the plants increased with increasing plant densities from 55,000 to 70,000 plants per hectare. In mid-season hybrid LG 50300 the height increased by 3.5 cm. In LG 5580 and LG 5662 hybrids, the height increased by 4 cm, and in the hybrids LG 5478 and LG 5638 a, the amount of height increase was 4.5 cm.

Thus, the increase in plant height in the studied hybrids is proportional to the increase in stem height, which is explained by the competition among plants for sunlight.

It should be noted that hybrids of LG 5478 and LG 5638 were the highest among the studied plants with indicators of 175.5–180.0 and 177.0–181.5 cm respectively. LG 5580 hybrid with plant height of 173.5–177.5 cm was slightly lower. The height of the plants of the hybrid LG 5662 ranged from 162.5 to 166.5 cm. The smallest in height and change in heights were plants of mid-season hybrid LG 50300 (156.5–160.0 cm).

Resistance of different sunflower hybrids to major diseases

Neglecting full sunflower growing technology often leads to the spread of pests and diseases. The main diseases of sunflower in Ukraine are root and head forms of white rot (*Sclerotinia sclerotiorum*), septoriose (*Septoria helianthi*), phoma rot (*Phoma helianthi*), stem canker (*Phomopsis helianthi*).

During 2018–2019, plants were examined and monitored for their diseases. Analyzing the data, we note that the crop densification led to an increase in the number of plants damaged by diseases.

Phoma rot (*Phoma helianthi*) least affected the plants of hybrids LG 5478 (the plants were not affected at all) and LG 5638 (the damage was observed when the crops were densified up to 70,000 plants/hectare). In LG 5662 hybrid, 15% of plants got the phoma rot disease at the higher density sowing, and 10% of plants were affected by disease with the density of 50000 plants/hectare (Table 2).

Phoma rot (*Phomahelianthi*) most affected plants of hybrids LG 50300 and LG 5580 – 12–27% and 15–32% respectively.

Stem canker (*P. helianthi*) caused the greatest damage to LG 5580 hybrid – 16% at the density of 70,000 plants/hectare, and at a lower density – 10%. At these

Table 2: The rate of sunflower hybrids stem diseases.

Hybrid	Crop density, (1000 plants per hectare)	Phoma rot (*Phoma helianthi*), %	Stem canker (*Phomopsis helianthi*), %	Leaf mottle (*Verticillium dahliae*), %	White rot (*Sclerotinia sclerotiorum*), %	Septoriose (*Septoria helianthin*), %	Blight (*Puccinia helianthin*), %	Broomrape (*Orobanche Cumana*), %
LG 50300	55	12	3	0	2	0	5	0
	70	27	10	0	5	9	10	0
LG 5580	55	15	10	0	0	0	12	0
	70	32	16	0	3	5	19	0
LG 5478	55	0	0	0	0	0	0	0
	70	0	0	0	0	0	0	0
LG 5638	55	0	0	0	0	0	0	0
	70	5	0	0	0	5	0	0
LG 5662	55	10	0	0	0	0	0	0
	70	15	0	0	0	5	0	0

densities LG 50300 hybrid was affected in the amount of 10 and 3% of plants, respectively. The hybrids LG 5478, LG 5638 and LG 5662 were not damaged by stem canker (*P. helianthi*).

Therefore, from the moment the head was formed to the full maturity of the seeds, not any sunflower hybrids were affected by the disease such as leaf mottle (*Verticillium dahliae*).

At the end of the flowering, sunflower plants of the two hybrids LG 50300 and LG 5580 at different crop densities were slightly affected by white rot (*Sclerotinia sclerotiorum*) by 2–5%, and other variants of experiments were not affected.

In the second half of summer, observing hybrids at the density of 70,000 plants/hectare, septoriose (*S. helianthi*) was detected in hybrids: LG 50300 – 9%, LG 5580, LG 5638 and LG 5662 – 5%. At the plant density of 55,000 plants/hectare that diseases were not detected on these hybrids. Only hybrid LG 5478 had no damage from septoriose (*S. helianthi*) at both studied densities.

At the end of vegetation season blight (*Puccinia helianthi*) was detected only in LG 50300 and LG 5580 sunflower hybrids at both plant densities for two years. 10% of LG 50300 hybrid was affected at the density of 70,000 plants/hectare and 5% at the density of 55,000 plants/hectare. LG 5580 hybrid with the density of 70,000 plants/hectare was affected by 19%, and at the density of 55,000 plants/hectare – 12%.

Broomrape (*Orobanche Cumana*) was not detected, since the experiments included the hybrids that are resistant to broomrape in the area.

Thus, increase crop density contributed to a higher incidence of diseases than the norm recommended by the seed producer. Among the hybrids, most common stem diseases were observed in LG 50300 and LG 5580. These hybrids are more susceptible to pathogens, regardless of plant densities, which is due primarily to their genetic characteristics. The hybrids LG 5478 and LG 5638 with different plant densities were most resistant to stem diseases for the period of 2018–2019. It should be noted that the level of disease spread did not significantly harm the productivity of crops of the studied hybrids.

Productivity of sunflower hybrids

Sunflower has a biological feature of maturing unevenly. Over time, the number of yellow sunflower heads increases, and those that have yellowed earlier should be harvested earlier. Later, as they dry, dry heads appear, gradually increasing. Thus, in the sunflower field, the plants have different degrees of ripeness, with the ratio among them changing over time. It is important in each case to determine the time of sunflower harvesting correctly.

Table 3: Influence of hybrid and plant densities on the elements of sunflower crop structure.

Hybrid	Crop density (1000 plants/ha)	Head diameter (cm)	Number of achenes per head	Mass of achenes per head (g)	Mass of 1000 seeds (g)
LG 50300	55	19.1	990	66.1	66.5
	70	16.2	835	51.3	61.3
LG 5580	55	21.2	1010	74.3	73.5
	70	18.2	880	56.2	64.0
LG 5478	55	21.8	1010	72.5	71.8
	70	18.3	870	57.4	66.0
LG 5638	55	21.9	960	65.8	68.8
	70	18.0	780	49.6	63.8
LG 5662	55	21.5	950	66.0	69.6
	70	18.6	840	54.1	64.6

We identified the diameter of heads at the time of harvesting (Table 3). Depending on the hybrid the diameter of the heads varies: at the plant density of 55,000 plants/hectare it is 19.1–21.9 cm, at the plant density of 70,000 plants/hectare it is 16.2–18.6 cm

LG 50300 hybrid had the smallest head diameter among all the hybrids under study, both at 55,000 plants/hectare – 16.2 cm and 70,000 plants/hectare – 19.1 cm density values. Thus, it can be concluded that increasing the density of sunflower crop in all the hybrids we study, leads to a decrease in the diameter of heads.

This trend was also noted for the number of seeds in one head. It varied from 780 in LG 5638 to 880 in LG 5580 at the density of 70,000 plants/hectare and from 950 in LG 5662 to 1010 in LG 5580 and LG 5478 at 55,000 plants/hectare. Thus, the number of achenes per head was greater at the lower plant density Also, absolutely all the hybrids under study, with increasing plant densities, reduced the mass of seeds per head (Table. 3). Therefore, at the density of 55,000 plants/hectare the indicator fluctuated within 65.8–74.3 g, and at the density of 70,000 plants/hectare it decreased to 49.6–57.4 g. At the same time LG 5580 and LG 5478 hybrids had best mass, and LG 5638 at different densities got worst mass of achenes peer head.

In the variants of the experiment, the weight of 1000 seeds on average varied from 61.3 to 73.5 g. It was the largest in the variants of LG 5580 and LG 5478 hybrids and plant density of 55,000 plants/hectare and was 73.5 and 71.8 g respectively. The lowest weight was in LG 50300 hybrid with crop density of 70,000 plants/hectare. In this variant, the weight of 1000 seeds was 61.3 g. This hybrid showed the smallest weight of 1000 seeds and at the density of 55,000 plants/hectare, which was 66.5 g.

An increase in the mass of 1000 seeds was gained in less density variants of the experiment (at the density of 55,000 plants/hectare). The difference in weight of 1000 seeds between crop density of 55,000 and 70,000 plants/hectare was in variants LG 50300 – 5.2 g, LG 5580 – 9.5 g, LG 5478 – 5.8 g, and LG 5638 and LG 5662 – 5.0 g.

Productivity is a major indicator in the cultivation of field crops, including sunflower. The level of productivity depends on many factors. The factor that significantly influences sunflower productivity is the length of the growing season, which is due to the ripeness of the hybrid. The duration of the growing season depends on the moisture of the seeds when harvesting.

During the harvest, the moisture of sunflower during the years of research was different. So, in 2018, seed moisture varied from 4.9 to 7.1%, and in 2019 from 5.8 to 9.4%. That is, in 2019, the moisture content of the seeds was slightly higher than in 2018.

As we can see, the longer the vegetation period of sunflower plants was, the higher was sunflower seed harvesting moisture. Thus, on average for 2018–2019, the highest harvesting moisture was in mid-season hybrids, while the lowest harvesting moisture was in early-season hybrids. The lowest moisture content of seeds at harvesting time was in early LG 50300 hybrid (5.5 and 5.6%), and the highest moisture in was in mid-season LG 5662 hybrid (7.9 and 8.1%) (Table 4).

Plant density had influence on the moisture of sunflower seeds during harvest. There is a clear tendency of decrease of seed moisture with higher crop density. For example, in the years of research in LG 50300, LG 5580 and LG 5638 hybrids at

Table 4: Productivity indicators of sunflower hybrids depending on crop density.

Hybrids	Crop density (1000 plants/ hectare)	Harvesting moisture (%)	Seed yield (t ha^{-1} with 7% moisture)	Oil content (%)	Oil yield (t ha^{-1})
LG 50300	55	5.6	3.60	51.1	1.84
	70	5.5	3.49	50.2	1.75
LG 5580	55	5.5	4.09	50.7	2.07
	70	5.4	3.88	50.4	1.96
LG 5478	55	6.8	3.99	52.3	2.09
	70	6.5	4.02	51.9	2.09
LG 5638	55	7.4	3.62	53.6	1.94
	70	7.3	3.42	53.0	1.81
LG 5662	55	8.1	3.57	49.8	1.78
	70	7.9	3.71	49.9	1.85
$LSD_{0.05}$			by factor A	0.14	
			by factor B	0.09	
			by factor AB	0.20	

higher crop density increased seed moisture at the time of harvest by only 0.1%, in the mid-season LG 5662 hybrid by 0.2%, and in LG 5478 hybrid by 0.3%.

Thus, a longer vegetation period of sunflower plants created the prerequisites for increasing the moisture content of the seeds at the time of harvest. Higher density of crops led to a decrease in seed moisture by 0.1–0.3%.

Monitoring sunflower seeds productivity showed that in 2018–2019 sunflower yields were formed due to the adaptive properties of the studied hybrids and their resistance to major harmful diseases. In 2018, the productivity was lower than in 2019. In 2018, it varied from 2.78 to 3.77 t ha^{-1}, and in 2019 from 4.00 to 4.47 t ha^{-1} (data are not present). The productivity of hybrids depended on the weather conditions during the years of research and crop densities.

Over the years, seed yield of hybrids has varied within 3.42–4.09 t ha^{-1}. The highest yields were provided by LG 5580 and LG 5478 hybrids, with productivity levels of 3.88–4.09 and 3.99–4.02 t ha^{-1}. The lowest productivity was recorded in LG 5638 hybrid – 3.42–3.62 t ha^{-1}.

Thus, in LG 50300, LG 5580 and LG 5638 hybrids the increase of density to 70,000 plants/hectare resulted in a lower crop productivity by 0.11, 0.21 and 0.20 t ha^{-1}, respectively. Only LG 5662 hybrid, record a sizable increase in productivity by 0.14 t ha^{-1} by increasing crop density, from 3.57 on 3.71 t ha^{-1}. Hybrid LG 5478 did not show a sizable response to the change in plant density.

Thus, increasing density of sunflower crops in the Steppe of Ukraine shows that not all hybrids will increase their productivity.

Modern sunflower hybrids are characterized by satisfactory uniformity, development and simultaneous maturation. They are resistant to diseases and stresses, resulting in the expected oil content of the crop.

The highest oil content, on average over the years, was formed in LG 5638 hybrid – 53.0–53.6%. A slightly lower oil yield from the seeds was in hybrid LG 5478, which was 51.9–52.3%. The lowest oil content was in hybrid LG 5662 – 49.8–49.9%.

The largest difference in oil content among the hybrids at different crop density was observed in LG 50300 hybrid and it was 0.9%, in LG 5638 hybrid it was 0.6%, in LG 5478 hybrid – 0.4%, in LG 5580 hybrid – 0.3%, and the least oil content (0.1%) was in LG 5662.

Thus, the increase of crop density from 55,000 to 70,000 plants/hectare resulted in 0.1–0.9% decrease in oil content at the time of harvest.

Conclusion

Studies have shown that productivity of sunflower hybrids did not depend on the crop density and varied in accordance with their genetic characteristics. Thus, the hybrids LG 50300, LG 5580 and LG 5638 showed higher productivity at 55,000 plants/hectare density with seed yield of 3.60, 4.09 and 3.62 t ha^{-1} respectively. The decrease in productivity of these hybrids in higher density was 0.11, 0.21 and 0.20 t ha^{-1}, respectively. LG 5478 hybrid showed a neutral response to the change in sowing density and only LG 5662 hybrid responded positively to crop densification with increasing productivity by 0.14 t ha^{-1}.

Also, increasing crop density from 55,000 to 70,000 plants/hectare resulted in a 0.1–0.9% decrease in oil content at the time of harvest.

According to the results of the research, it is possible to recommend farmers growing hybrids LG 50300, LG 5580, LG 5478, and LG 5638 with the density of 55,000 plants/hectare in the conditions of the Steppe of Ukraine, except for LG 5662 hybrid, which revealed tolerance to the increase of density of its crops.

References

Budennyi, Y.V., Zuza, V.S., and Trigub, A.S. (1987). To reduce the harm of rot. Oilseeds 1: 28–29 (Ru).

Diakov, A.B. (1984). Competition among crops and stability of their productivity. Economic genetics of plants and animals, Vol. 250. Novosibirsk: Nauka (Ru).

Harbar, L.A., and Horbatiuk, E.M. (2017). Specific features of productivity formation of sunflower crops. Bull. Poltava State Agrarian Acad. 1–2: 24–26 (Ukr).

Hrabovskyi, M.B. (2010). Influence of crop density on economically valuable features and sunflower productivity in the conditions of central forest-steppe of Ukraine. Bull. Grain Inst. 38: 88–91 (Ukr).

Ibrahim, H. (2012). Response of some sunflower hybrids to different levels of plant density. APCBEE Proc. 4: 175–182.

Khmarskyi, M. (2017). Influence of sowing time and density on sunflower productivity. Proposition. Special issue. In: Sunflower: simple solutions to difficult questions, K.: Univest Media. pp. 36–37 (Ukr).

Korytnyk, V.M., Bondarenko, M.P., and Pysmennyi, A.H. (2001). Identification of optimal plant densities depending on the group of ripeness of hybrids, sowing time, row spacing and the contribution of these factors to the formation of sunflower crop in the North-Eastern region of Ukraine. Bull. Grain Inst. 17: 62–64 (Ukr).

Koshkin, E.I., Gataulina, G.G., Diakov, A.B., and other. (2005). Partial physiology of field crops, Vol. 344. Moskva: Koloss (Ru).

Lisovyi, M.P. (2002). Methodology and basics of the concept of plant protection in Ukraine. Bull. Agrar. Sci. 9: 25–28 (Ukr).

Lykhochvor, V.V. (2004). Crop growing. Technologies for growing crops, Vol. 808. Kyiv: Centre of Educational Literature (Ukr).

Minkovskyi, A.I. (2000). The response of sunflower hybrids to row spacing, crop density and weed competitiveness. Bull. Grain Inst. 14: 27–29 (Ukr).

Mostipan, M.I., Vasylkovska, K.V., Andriyenko, O.O., and Reznichenko, V.P. (2017). Modern aspects of tilled crops productivity forecasting. INMATEH Agric. Eng. 53: 35–40.

Nahornyi, V.I. (2001). Sowing density as a factor in increasing productivity of crops. Bull. Sumy State Agrar. Univ. 5: 81–82 (Ukr).

Nedealcov, M., Duca, M., and Dencicov, L. (2017). Sunflower's productivity in the context of climatic changes on Republic of Moldova's territory. HELIA 40: 115–132.
Oleksiuk, O.M. (2000). Influence of sowing methods and plant density on the productivity of sunflower hybrids in the northern part of Steppe Ukraine. Dissertation for the degree of Candidate of Agricultural Sciences, specialty 06.01.09 "Plant growing". National Academy of Agricultural Sciences of Ukraine. Dnepropetrovsk: Institute of Grain Management 16 (Ukr).
Onopriienko, V.P. (1998). Productivity of sunflower seeds and their quality depending on the area of feeding. Bull. Sumy State Agrar. Univ. 2: 50–52 (Ukr).
Orlov, A. (2013). Sunflower. Biology, cultivation, diseases and pests. Zerno 624 (Ru).
Semerci, A. (2012). Productivity analysis of sunflower cultivations in Turkey. Bulg. J. Agric. Sci. 18: 873–882.
Spitzer, T., Bílovský, J., and Kazda, J. (2018). Effect of using selected growth regulators to reduce sunflower stand height. Plant. Soil Environ. 64: 324–329.
Tkalich, I.D., Tkalichand, Y.I., and Rychik, S.G. (2011). Sun flower (basics of biology and sunflower agriculture: monograph). Dnepropetrovsk 172 (Ukr).
Vasylkovska, K.V., Leshchenko, S.M., Vasylkovskyi, O.M., and Petrenko, D.I. (2016). Improvement of equipment for basic tillage and sowing as initial stage of harvest forecasting. INMATEH Agric. Eng. 50: 13–20.