

Morphological Features of Plants and Yield of Sunflower Hybrids Cultivated in the Northern Part of the Forest-Steppe of Ukraine

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Abstract

In Ukraine, a sunflower is the main oil crop from which more than 90% of vegetable fats are produced. An increase in production is due to the expansion of cultivation area, which necessitates research on sunflower hybrids adaptability in the northern regions of Ukraine, where in recent decades, there has been a significant change of weather conditions and which may be favorable for its cultivation. The research was carried out in the Northern part of the Forest-Steppe of Ukraine on light loam chernozems. Reaction to growing conditions of four hybrids was studied by establishing the stability and plasticity of hybrids in terms of yield formation due to changes in morphological characteristics of plants. Yield potential realization is high enough, which is provided by sufficient amounts of positive, active, effective temperatures and precipitation. Calculation of the coefficients of plasticity and stability allows identifying stable sunflower hybrids, hybrids with a high level of plasticity, and recommending them to production. The yield of early-maturing hybrid Ukrainskyi F1 increases rectilinearly with plant density increasing ($r = 0.977 - 0.998$), while hybrids P63LL06 ($r = 0.651 - 0.882$); NK Ferti ($r = 0.589 - 0.846$), and NK Brio ($r = 0.689 - 0.804$) form a higher yield at standing densities up to 60 thousand plants per hectare, and with further thickening, the yield decreases. With the thickening of sowings, the height of all hybrids plants increases ($r = 0.97 - 0.99$), and there is a decrease in the number of seeds per antherode, and the weight of 1000 seeds. Sunflower hybrids can be divided into the groups according to the peculiarities of yield formation due to morphological features: 1) yield increases only due to sowings' thickening—Ukrainskyi F1; 2) combined efficiency-increasing sowings' density to 60 thousand plants/ha and generative organs formation—NCKBrio; 3) hybrids of intermediate type—NK Ferti and P63LL06.

Keywords

Sunflower, Yield, Plasticity, Stability, Plant Height, The Weight of 1000 Seeds, Individual Plant's Productivity

1. Introduction

Global change of climate and weather conditions, growing needs of mankind for food, energy plant resources, raw materials for industrial processing, and other urgent human needs requires crop production expansion [1] [2] [3] [4] [5]. At the same time, crop production should be economically and environmentally feasible. In recent years, Ukraine has been expanding the production of an important oil crop of universal use—sunflower [6]. The sown areas of sunflower (*Helianthus annuus*)—a traditional culture of the Steppe zone are actively moving to the Northern regions of Ukraine [7]. Establishing of hybrids' adaptability, peculiarities of their productivity formation, dependences of vegetative and generative organs formation, depending on weather and technological factors is relevant.

2. Literature Survey

2.1. Significance and State of Sunflower Production

Sunflower is a crop that is widespread in the southern regions of Europe and Ukraine in particular. In recent years, due to significant changes in weather conditions—increasing in air temperature, and a prolongation of the period with air temperatures above 8°C - 10°C in the northern regions, there has been an expansion of the geographical zone of sunflower cultivation. Establishing the features of sunflower cultivation and development of adaptive cultivation technologies is an important area of research for the northern regions of Europe and Ukraine [8].

In Ukraine, the main oil crop is a sunflower, which produces over 90% of vegetable fats. Gross sunflower production in Ukraine has increased to 12 million tons in recent years. Between 2010 and 2019, the area under sunflower in Ukraine increased by almost one and a half million hectares and reached 6.1 million hectares. Ukraine is a leader in sunflower production and the largest exporter of sunflower oil in the world—5, 6 million tons (57% of total exports in 2018). The gross harvest of sunflower seeds increase was mainly due to the expansion of sown areas. A feature of the soil-climatic zone of the Steppe of Ukraine, where sunflower is mainly grown, is an insufficient amount of precipitation with a significant potential of solar energy. Due to such natural features, almost every year there is an acute shortage of soil moisture, which prevents the planned level of yield [9]. With high plowing levels of soils and oversaturation of crop rotations by sunflower, specific diseases and pests are spread. All this necessitates research on the adaptability of sunflower hybrids in the Northern regions of Ukraine, where in recent decades there has been a significant change in

weather conditions and which may be favorable for sunflower growing.

2.2. The Adaptability of Sunflower Plants to Growing Conditions

The task of creating and implementing in production hybrids with high yield potential with optimization of growing conditions is complicated by the problem of ecological adaptation: the potential of production conditions can't grow adequately to the growth of genetically determined yield potential of varieties [10] [11] [12]. The ability to economically and efficiently use environmental factors is a highly adaptive genotype property [13]. The adaptability of hybrids is an extremely important feature of variable abiotic and biotic environmental factors [14] [15]. Sunflower is a culture of the temperate zone and is quite flexible to weather and soil conditions [16] [17]. Sunflower is a salt-tolerant crop [18]. Sunflower is characterized by high adaptability and yield [8]. Optimally formed plant population of sunflower influence the quality of seed for processing [19] [20].

2.3. Morphological Features of Plants, Sunflower Yield Depending on Plants' Density

The level of varieties' and hybrids' biological potential realization depends on both—growing technology and climatic conditions of a particular year and their interaction [21] [22] [23] [24]. Sunflower yield is determined by several factors, among which the role of hybrid and plants' standing density are among the determinants [25] [26]. Agrocenosis formation with an optimal plant density and optimal nutrients supply provides an increase in its productivity [27] [28].

Morphological characteristics of the plant are varietal characteristics, but under the influence of environmental factors and cultivation technologies, they may change [29]. Under the influence of nitrogen fertilizers, a yield increase of sunflower hybrids, an increase in the anther diameter was recorded [30] [31] [32]. The height of plants with plants standing density increasing usually increases, especially with using irrigation [33]. There is also a decrease in the weight of 1000 seeds and seeds number from the anther [34]. However, with plant density increasing, competition for light between plants increases, which leads to a decrease in vegetative and reproductive plasticity of the plant [35], while lower plant density leads to reduced light absorption by plants what leads to a reduction in yield per unit area [36] [37] [38]. Theoretical studies and practical experience have shown that high yields per unit area are usually associated with low plant competitiveness due to reduced anther diameter, plant biomass, weight of 1000 seeds, seed yield per plant, unsaturated fatty acids [39] [40].

3. Conditions and Methods of Research

In the Northern part of the Left Bank Forest-Steppe of Ukraine (Bakhmach, Chernigiv region (51.1513819, 32.8623028)) during 2016-2018 field studies were conducted for the identification sunflower hybrids of different ecotype by mor-

phological characteristics, stability, and yield plasticity under variable weather conditions. Multifactor field experiment was based on the following scheme: factor A—“hybrid”: “Ukrainskyi F1”, “P63LL06”, “NK Brio”, “NK Ferti”; factor B—“density of plants’ standing”: 50, 55, 60, 65 thousand pieces/ha. The area of the accounting plot is 50 m², repeating is quadruple.

In the experiment, hybrids of different selection were used, which differ in growth intensity at the initial microstages of development, which requires additional research for sunflower cultivation in the northern regions of Ukraine:

Ukrainskyi F1 (selection of Ukraine)—an early-ripening hybrid—develops rapidly in the initial microstages.

P63LL06 (selection of Pioneer)—a medium-early-ripening hybrid with sufficiently high growth energy at the initial microstages.

NK Brio (selection of Syngenta)—a medium-ripening hybrid—early in its maturity group. Initial growth is slow.

NK Ferti (selection of Syngenta)—a medium-ripe hybrid with medium growth energy in the initial stages.

Originators of hybrids give recommendations on plant density, but depending on weather conditions and soil, hybrids respond differently to crop density, so identifying the optimal crop density of a particular hybrid is extremely important. For the study, we chose a step to change the density of standing plants with a difference of 5 thousand plants/ha from the density recommended by the authors of hybrids.

The soil of experimental plots is light loam chernozem with humus content 2.98%. The reaction of soil solution is close to neutral, pH—5.9 - 6.2. The weighted average content of mobile forms of phosphorus is 132 mg/kg of soil, exchangeable potassium is 94 mg/kg of soil, the content of exchangeable calcium and magnesium is increased, respectively 10.6 and 2.2 mg-eq/100 g of soil. Soil quality—69 points, and therefore in general the soil of the experimental area has favorable agrophysical properties and relatively high natural fertility, which allows growing sunflowers successfully.

The field was plowed to a depth 28 - 30 cm, and after plowing, for weeds destroying and leveling the soil, cultivation to a depth 8 - 10 cm was used. In the spring—soil moisture conservation by spring harrowing. Fertilized by anhydrous ammonia—123.3 kg/ha in the nitrogen active substance; under pre-sowing cultivation was applied N₁₆P₃₈P₅₈ in the active substance. During sowing, a complex fertilizer N₈P₂₄K₂₄S₅, in the active substance, was applied in the row area.

Soil herbicide Primextra TZ Gold 500 was applied at the rate 4 l/ha. Fungicide Propulse at the rate 1 l/ha with simultaneous application of YaraVita BORTRAC 150 at the rate 1 l/ha was used for prevention diseases. The sunflower hybrids were sown in the third decade of April: April 20th; April 22nd; April 25th, respectively, in 2016, 2017, 2018. Seedlings in all three years of research appeared on May 2-3. Hybrids reached full maturity (15% of seed moisture) in the last decade of August—after August 25th. The sunflower was harvested with 7% of seed moisture in the I - II decade of September.

Determination of stability and plasticity of hybrids by yield was performed according to the Eberhard-Russell method, while for the criterion “point” we used the criterion “weather conditions of the year” [41]. In this modification, we determined the stability and plasticity of the hybrids relative to the meteorological conditions of the research site.

Sunflower yields were accounted for each site by combine harvesting.

Statistical data processing was performed using the software package SAS 9.4.

4. Results of Research

4.1. Weather Conditions of the Research Region

The climate of the district is temperate-continental. The average temperature in July is +20°C. The average January temperature is between –6°C and –8°C. The growing season lasts an average of 200 - 210 days. The period, when the average daily temperature exceeds +15°C, is approximately 110 days. Annual sum of temperatures exceeding +10°C is 2500 - 2600. Period without light frosts on the soil surface lasts about 135 - 140 days. Precipitation averages about 550 - 600 mm. The biggest amount of precipitation, about 75%, falls from April to October.

The analysis of average daily air temperatures was performed in the matching of long-term data to 2005-2015. The average daily temperature only in April steadily passes over +10°C, but the dynamics of temperature rise over the years are quite different. The average daily air temperature is quite moderate and during the period of active sunflower’s vegetation varies from 14.0°C to 21.6°C. The sum of temperatures, both at a biological minimum temperature 10°C and 5°C, corresponds to the biological needs of sunflower plants and is not a limiting factor of cultivation. The sum of thermal units for the period April-October, on average for three years, is 3780. During the period of active sunflower vegetation (April-August) the sum of thermal units is 2868 - 3258, significantly exceeding the sum of active and effective temperatures at biologically active temperatures 5°C and 10°C.

In the research area, the maximum temperatures are quite comfortable—do not exceed 30°C, with some exceptions (the second decade of August 2017—36°C). Temperatures in the range up to 30°C promote the formation and development of generative organs.

The average amount of precipitation according to long-term data is 556 mm, in the years of research it was: 849, 592, 516 mm, respectively, in 2016, 2017, 2018. However, during the period of sunflower’s active vegetation (May-September) precipitation was 390, 247, 211 mm, respectively, in 2016, 2017, 2018. Hybrids differ significantly by their response to moisture, maximum and minimum temperatures, and other factors.

4.2. Plasticity and Stability of Hybrids by Yield

Growing of sunflower hybrids in the Northern part of the Left-Bank For-

est-Steppe of Ukraine produces a consistently high yield. During 2016-2018, yield of hybrids ranged: Ukrainskyi F1—2.16 - 3.11; P63LL06—2.58 - 3.52; NK Brio—3.20 - 4.12; NK Ferti—2.79 - 3.79 t/ha (**Table 1**). The productivity of sunflower is determined by genetically determined features, but within certain limits, they can change under the influence of environmental factors.

Calculated coefficients of plasticity and yield stability indicate favorable conditions for yields of sunflower hybrids formation.

Stability coefficient for hybrid “Ukrainskyi F1” was 1.68 - 2.30; “P63LL06”—2.51 - 3.14; “NK Brio”—3.15 - 4.63; “NK Ferti”—2.70 - 3.75.

The early-ripening hybrid “Ukrainskyi F1” is approaching its maximum in terms of the level of yield potential realization, in the conditions of research. Coefficients of plasticity among the studied hybrids are the lowest—2.36 - 2.97 and with an average yield of 2.41 - 2.81 t/ha shows bigger stability—1.68 - 2.30 compared to other sunflower hybrids. Hybrid “NK Brio” is highly plastic and, as the results show, the yield potential of this hybrid in the Northern part of the Left-Bank Forest-Steppe has not been fully realized. The maximum yield of the hybrid was formed with a rate of 60 thousand plants/ha - 3.93 t/ha and the coefficient of plasticity increased to 4.84 with a stability coefficient 4.63.

Table 1. Plasticity and yield stability of sunflower hybrids.

Hybrid	The density of plants' standing, thousand pieces/ha	Y_i^1 , t/ha	b	σ^2
Ukrainskyi F1	50	2.41	2.36	1.68
	55	2.55	2.69	1.83
	60	2.70	2.74	1.98
	65	2.81	2.97	2.30
P63LL06	50	2.91	2.93	2.51
	55	3.02	3.30	2.68
	60	3.37	4.14	3.14
	65	3.20	3.93	3.02
NK Brio	50	3.32	4.34	3.15
	55	3.61	4.50	3.53
	60	3.93	4.84	4.63
	65	3.67	4.34	3.95
NK Ferti	50	3.00	3.29	2.7
	55	3.18	3.59	3.01
	60	3.57	4.33	3.75
	65	3.34	3.77	3.20

Notes: ¹ Y_i —average yield; ² b —coefficient of plasticity; ³ σ^2 —coefficient of stability.

4.3. Structural Components of Sunflower Hybrids' Yields

The yield of sunflower hybrids significantly depends on plants' standing density and this is the predominant factor in yields' formation. The individual yield of plant decreases due to crop thickening, but due to the increase of plants' number in the area, the yield also increases.

Reaction to the sowings' thickening was manifested through a change in the yield structure. The early-maturing hybrid "Ukrainskyi F1" formed a lower yield compared to other hybrids (Table 2).

Yield of early-ripening hybrid "Ukrainskyi F1" increases rectilinearly with plant density increasing ($r = 0.977 - 0.998$), while hybrids P63LL06 ($r = 0.651 - 0.882$); "NK Ferti" ($r = 0.589 - 0.846$) and "NK Brio" ($r = 0.689 - 0.804$) form a higher yield at standing densities up to 60 thousand plants per hectare, and with further thickening the yield decreases.

Height of sunflower plants is largely determined by the morphological features of a hybrid, varying slightly over the years: "Ukrainskyi F1"—173.5 - 177.8; "P63LL06"—184.1 - 188.4; "NK Brio"—167.5 - 171.5; "NK Ferti"—181.9 - 187.2 cm (Tables 2-5). With sowings thickening, the plants' height of all hybrids increases ($r = 0.97 - 0.99$).

Hybrid "P63LL06" occupied an intermediate position between hybrids - forming a yield in a favorable for weather conditions year (2018) from 3.26 to 3.52 t/ha and in years with less favorable conditions—from 2.58 to 3.20 t/ha. The diameter of the anther varies from 20.1 to 25.9 cm. The number of seeds in the anther varies from 654 to 712 pieces, and the weight of seeds from the anther is 44.5 - 54.8 grams. Plants of the hybrid have a stable height, which ranges from 184.1 to 187.8 cm (Table 3).

Hybrid "NK Brio" in all years of research and at different densities stood the highest yields (Table 4).

The hybrid formed anthers with the largest diameter among the studied hybrids—from 24.0 to 27.7 cm, in which 748 - 831 achenes were differentiated, and their weight was 53.1 - 65.3 g. Quantitative reduction of yields structural components occurred with the thickening of sowings and less precipitation during the period of achenes' differentiation. The plants of hybrid "NK Brio" were the lowest compare to other hybrids—167.5 - 171.5 cm, but the stem diameter was the largest—2.9 - 3.5 cm.

Hybrid "NK Ferti" yielded slightly relative to the yield of hybrid "NK Brio" (Table 5). According to the morphological features, plants of hybrid "NK Brio" differed from "NK Ferti". The diameter of the anther varied from 18.5 to 23.4 cm. The number of achenes in the anther 656 - 706, and the mass of achenes in the anther—45.5 - 54.4 g. The mass of 1000 seeds was 69 - 77. Dependencies between yield and structure components show, that a close correlative positive relationship was established for yield and plants density in the sowings ($r = 0.589 - 0.846$); plant height ($r = 0.616 - 0.883$); leaf surface index ($r = 0.633 - 0.851$). However, these connections are not as close as in the hybrid "Ukrainskyi F1".

Table 2. Morphological features and yield of hybrid Ukrainskiy F1.

Year	The density of the plants' standing, thousand pc/ha	Yield, t/ha	Number of seeds, pc/anthode	Mass of seed, g/anthode	The diameter of anthode, cm	Plant height, cm	The diameter of the stem, cm
2016	50	2.32 ^c	569 ^b	42.1 ^b	24.2 ^{bc}	173.5 ^b	2.7 ^b
	55	2.44 ^b	556 ^b	40.0 ^b	22.5 ^{bc}	174.8 ^b	2.7 ^b
	60	2.68 ^a	550 ^b	38.5 ^a	21.6 ^{bc}	175.6 ^b	2.4 ^{bc}
	65	2.79 ^a	544 ^b	37.5 ^b	20.3 ^{bc}	176.3 ^b	2.1 ^{bc}
	Average	2.56 ^a	555 ^b	39.5 ^b	22.2 ^{bc}	175.1 ^b	2.5 ^a
2017	50	2.16 ^c	561 ^b	41.0 ^{ab}	23.9 ^b	175.2 ^b	2.8 ^{ab}
	55	2.26 ^{bc}	549 ^{bc}	39.0 ^{ab}	22.3 ^b	175.8 ^b	2.6 ^{ab}
	60	2.40 ^b	542 ^b	37.4 ^a	21.2 ^b	176.6 ^b	2.5 ^a
	65	2.53 ^a	518 ^b	34.7 ^a	20.4 ^b	177.1 ^b	2.3 ^b
	Average	2.34 ^b	543 ^b	38.0 ^b	21.9 ^b	176.2 ^b	2.6 ^{ab}
2018	50	2.75 ^c	583 ^b	43.1 ^{bc}	24.6 ^b	176.1 ^b	2.7
	55	2.9 ^b	568 ^{bc}	41.5 ^{bc}	23.8 ^b	176.4 ^b	2.7 ^b
	60	3.02 ^a	554 ^c	38.8 ^{bc}	23.2 ^b	177.1 ^b	2.5 ^b
	65	3.11 ^a	550 ^c	38.5 ^a	22.4 ^b	177.8 ^c	2.4 ^b
	Average	2.96 ^a	564 ^c	40.5 ^{bc}	23.5 ^b	176.9	2.6 ^b

Note: Significant differences ($p < 0.05$) between the values in the column are identified by different letters.

Table 3. Morphological features and yield of hybrid P63LL06.

Year	The density of plants' standing, thousand pc/ha	Yield, t/ha	Number of seeds, pc/anthode	Mass of seed, g/anthode	The diameter of anthode, cm	Plant height, cm	The diameter of the stem, cm
2016	50	2.88 ^b	707 ^b	53.7 ^b	25.4 ^b	184.1 ^b	2.9 ^b
	55	2.99 ^b	698 ^b	51.0 ^b	22.7 ^b	185.8 ^b	2.7 ^b
	60	3.48 ^a	697 ^b	50.2 ^b	22.0 ^b	187.2 ^b	2.5 ^b
	65	3.20 ^a	667 ^b	46.0 ^b	20.1 ^b	188.4 ^b	2.4 ^b
	Average	3.14	692 ^b	50.2 ^b	22.6 ^b	186.4 ^b	2.6 ^b
2017	50	2.58 ^b	703 ^b	52.0 ^b	25.6 ^{bc}	185.1 ^{bc}	2.8 ^{bc}
	55	2.75 ^b	687 ^b	49.5 ^{ab}	22.5 ^{bc}	186.3 ^{bc}	2.8 ^{bc}
	60	3.12 ^a	672 ^b	47.0 ^{ab}	22.4 ^b	186.9 ^{bc}	2.6 ^b
	65	3.02 ^a	654 ^{ab}	44.5 ^b	20.8 ^b	187.8 ^b	2.5 ^b
	Average	2.87	679 ^{ab}	48.2 ^{ab}	22.8 ^b	186.5 ^b	2.7 ^b
2018	50	3.26 ^b	712 ^{ab}	54.8 ^{ab}	25.9 ^{bc}	185.3 ^b	2.8 ^{bc}
	55	3.31 ^{ab}	704 ^{ab}	52.1 ^{ab}	25.6 ^{bc}	185.7 ^b	2.7 ^b
	60	3.52 ^a	703 ^a	51.3 ^b	23.1 ^b	186.0 ^b	2.6 ^b
	65	3.38 ^a	695 ^a	48.7 ^b	21.7 ^b	186.3 ^b	2.4 ^b
	Average	3.37	704 ^{ab}	51.7 ^b	24.1 ^b	185.8 ^b	2.6 ^b

Note: Significant differences ($p < 0.05$) between the values in the column are identified by different letters.

Table 4. Morphological features and yield of hybrid NK Brio.

Year	The density of plants' standing, thousand pc/ha	Yield, t/ha	Number of seeds, pc/anthode	Mass of seed, g/anthode	The diameter of anthode, cm	Plant height, cm	The diameter of the stem, cm
2016	50	3.34 ^b	826 ^b	65.3 ^{bc}	27.2 ^{bc}	167.8 ^b	3.4 ^b
	55	3.63 ^b	823 ^b	61.7 ^b	26.8 ^{bc}	168.8 ^b	3.3 ^b
	60	3.98 ^a	814 ^a	59.4 ^a	26.3 ^b	169.6 ^b	3.1 ^b
	65	3.69 ^a	769 ^a	55.4 ^a	24.4 ^b	169.9 ^b	3.0 ^b
	Average	3.66	808 ^b	60.4 ^b	26.2 ^b	169.0 ^b	3.2 ^b
2017	50	3.20 ^{bc}	790 ^b	60.8 ^b	26.8 ^a	167.5 ^b	3.3 ^b
	55	3.41 ^{bc}	775 ^b	57.4 ^b	26.2 ^a	168.4 ^b	3.2 ^b
	60	3.68 ^a	764 ^b	55.0 ^b	25.7 ^a	168.9 ^b	3.2 ^{ab}
	65	3.41 ^a	748 ^{ab}	53.1 ^b	24.0 ^a	169.6 ^b	2.9 ^{ab}
	Average	3.43	769 ^b	56.6 ^b	25.7 ^a	168.6 ^b	3.2 ^{ab}
2018	50	3.43 ^b	831 ^{ab}	65.6 ^{bc}	27.7 ^{bc}	168.5 ^c	3.5 ^b
	55	3.78 ^b	828 ^{ab}	62.1 ^{bc}	27.6 ^b	169.2 ^c	3.3 ^b
	60	4.12 ^a	827 ^{ab}	61.2 ^b	26.3 ^b	170.4 ^b	3.3 ^{ab}
	65	3.92 ^a	802 ^a	56.1 ^b	25.2 ^b	171.5 ^b	3.1 ^{ab}
	Average	3.81 ^a	822 ^{ab}	61.3 ^b	26.7 ^b	169.9 ^b	3.3 ^{ab}

Note: Significant differences ($p < 0.05$) between the values in the column are identified by different letters.

Table 5. Morphological features and yield of hybrid NK Ferti.

Year	The density of plants' standing, thousand pc/ha	Yield, t/ha	Number of seeds, pc/anthode	Mass of seed, g/anthode	The diameter of anthode, cm	Plant height, cm	The diameter of the stem, cm
2016	50	3.04 ^{ab}	697 ^{bc}	53.0 ^{ab}	23.4 ^b	182.5 ^b	2.8 ^{bc}
	55	3.10 ^{ab}	692 ^{bc}	51.2 ^{ab}	22.1 ^a	183.8 ^b	2.8 ^b
	60	3.56 ^a	689 ^b	51.0 ^a	20.4 ^a	185.1 ^a	2.7 ^a
	65	3.24 ^a	656 ^b	45.9 ^a	19.3 ^a	186.2 ^a	2.5 ^a
	Average	3.24 ^{ab}	684 ^b	50.3 ^a	21.3 ^a	184.4 ^b	2.7 ^b
2017	50	2.70 ^{bc}	682 ^c	51.2 ^b	22.8 ^b	181.9 ^b	2.7 ^b
	55	2.96 ^b	678 ^{bc}	50.2 ^b	21.7 ^b	182.8 ^b	2.6 ^b
	60	3.36 ^a	671 ^b	48.3 ^{bc}	20.1 ^a	184.6 ^a	2.6 ^b
	65	3.12 ^a	659 ^b	45.5 ^b	18.5 ^a	186.1 ^a	2.5 ^b
	Average	3.04 ^b	673 ^b	48.8 ^b	20.8	183.9	2.6
2018	50	3.27 ^{bc}	706 ^{bc}	54.4 ^b	23.6 ^a	183.2 ^a	2.9 ^b
	55	3.48 ^b	701 ^{bc}	51.9 ^b	22.2 ^a	183.8 ^a	2.9 ^b
	60	3.79 ^a	698 ^b	51.0 ^b	20.7 ^a	186.4 ^a	2.8 ^a
	65	3.66 ^a	663 ^b	46.4 ^a	19.8 ^a	187.2 ^a	2.6 ^a
	Average	3.55 ^a	692 ^b	50.9 ^b	21.6 ^a	185.2 ^a	2.8

Note: Significant differences ($p < 0.05$) between the values in the column are identified by different letters.

4.4. Correlative Dependence of Hybrids' Yield and Sowing Structure

With a positive correlation between yield and plant density, we found an inverse correlation of different strength relationship between yield and number of seeds in the antherode: Ukrainskyi F1— $r = -0.957 - 0.987$; P63LL06— $r = -0.333 - 0.864$; NK Brio— $r = -0.262 - 0.552$; NK Ferti— $r = -0.164 - 0.623$ in years with different weather conditions (Table 6).

Seed differentiation in antherodes has an inverse correlation to the density of plants' standing ($r = -0.935$). With plant density increasing, the number of seeds in the antherodes decreases. This dependence was observed for all studied hybrids.

The yield of sunflower hybrids directly depends on the leaf surface index, but for hybrids this dependence is different. Correlation between these indicators for hybrid Ukrainskyi F1 is close ($r = 0.965$); NK Ferti— $r = 0.757$; P63LL06— $r = 0.689$; NK Brio— $r = 0.680$. So, it can be argued that the yield potential of hybrids P63LL06, NK Ferti, NK Brio depends on the increase of the leaf surface index. Sowings of hybrid Ukrainskyi F1 form the leaf surface area, which ensures the realization of the biological potential of the hybrid.

Table 6. Correlation dependences of yield and morphological characteristics of sunflower plants.

Hybrid	Year	Connections ¹						
		Y*D	Y*N	N*D	Y*W	H*D	Y*H	Y*IL
Ukrainskyi F1	2016	0.989	-0.957	-0.978	-0.989	0.989	0.973	0.986
	2017	0.998	-0.971	-0.969	-0.998	0.996	0.996	0.999
	2018	0.977	-0.984	-0.974	-0.912	0.986	0.928	0.971
	Average	0.988	-0.971	-0.974	-0.966	0.990	0.965	0.986
P63LL06	2016	0.709	-0.333	-0.897	-0.597	0.997	0.736	0.639
	2017	0.882	-0.864	-0.999	-0.882	0.992	0.863	0.869
	2018	0.651	-0.478	-0.966	-0.537	0.997	0.665	0.559
	Average	0.747	-0.558	-0.954	-0.672	0.995	0.775	0.689
NK Brio	2016	0.689	-0.262	-0.877	-0.825	0.976	0.823	0.681
	2017	0.804	-0.552	-0.998	-0.730	0.994	0.599	0.537
	2018	0.804	-0.363	-0.845	-0.737	0.994	0.766	0.822
	Average	0.766	-0.392	-0.907	-0.764	0.988	0.729	0.680
NK Ferti	2016	0.589	-0.164	-0.873	-0.234	0.999	0.616	0.633
	2017	0.773	-0.623	-0.973	-0.640	0.992	0.749	0.788
	2018	0.846	-0.474	-0.869	-0.777	0.967	0.883	0.851
	Average	0.736	-0.421	-0.905	-0.551	0.986	0.749	0.757

Note. Y—yield; D—density of plants' standing; N—number of seeds in the antherode (on the plant), W—the weight of 1000 seeds; H—plants height; IL—leaf surface index. Actual at $P < 0.01$.

5. Discussion

Studies show growing of sunflower hybrids in the Northern part of the For-est-Steppe of Ukraine is highly efficient. Yield potential realization is quite high, which is provided by the necessary amounts of positive, active, and effective temperatures and sufficient precipitation. Determining the coefficients of plasticity and plasticity allows us to identify stable sunflower hybrids, hybrids with a high level of plasticity and to recommend them for production in the growing regions. Adaptive technological factors cause increased stability of yield's sunflower hybrids.

6. Conclusions

Due to the formation of sunflower agrocenosis with optimal plant density provides an increase in its productivity.

Sunflower hybrids can be divided into several groups, according to the peculiarities of yield formation: 1) yield increases only due to sowings thickening—Ukrainskyi F1; 2) combined efficiency—due to increasing the density of sowings up to 60 thousand plants/ha and generative organs formation—NK Brio; 3) hybrids of intermediate type—NK Ferti and P63LL06.

The optimal density of early-maturing hybrids plants standing is not less than 65 thousand pieces/ha and of medium-ripe hybrids—the optimal density—60 thousand pieces/ha.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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