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Study of the possibilities of using sunflower lines with different colours of seeds to create poultry feed

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Abstract: Sunflower is used for the production of oil, confectionery and animal feed. Birds are very fond of sunflowers and can be pests of sunflower crops, and are consumers of seeds. Sunflower poultry feed is an emerging market that determines the direction of breeding. Its development is based on the determination of bird preferences and the available variety of sunflower lines. This is what our research is devoted to. Experimental feeding of chickens with a mixture of sunflower seeds of different colours was carried out. Chickens have been found to prefer contrasting striped seeds with white and dark stripes more than others. The white colour of the seeds was eaten less than others. Studies of the genetics of sunflower colour allow us to distinguish two groups of lines by seed colour. The first has white seeds with the EwEwPP genotype, suitable for use in human confectionery and more protected from being eaten by wild birds in the fields. The second is striped seeds with the EstrEstrPP genotype, which can be fed whole seeds to birds. Donors of seed colour traits and other traits important for hybrid breeding were selected from the evaluated collection of sunflower lines. InK1039 line is a donor of small striped seeds and pollen fertility restoration. InK1587 line is a sterility fixer and donor of striped and early maturing seeds. To create hybrids with white seeds for human consumption and thus more resistant to ingestion by wild birds, white seed donors were isolated with KG9 to restore pollen fertility and I2K2218 in a pollen sterility fixer.

Keywords: birds; food; hybrids; line; seed colour; sunflower.

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Introduction

Sunflower is one of the main crops of Ukraine. It has a very large variety in seed quality. In addition to the usual oil use, two specific uses of hybrids and varieties of sunflower have already been identified. The first is with a changed composition of oil (predominantly oleic), which is advantageous to use for the manufacture of solid fats. The second is the use of sunflower seeds on the core for confectionery purposes and in general toasted form. These areas have been studied and developed for more than 20 years. Varieties and hybrids of special-purpose sunflower have reliably entered our lives. However, the possibilities of sunflowers do not end there. Currently, producers are already asking questions about sunflower in a new specific area of use – poultry feed.

The property of birds' preference for certain types of seeds in terms of size and colour, species affiliation has been observed by many scientists. The preferences of tits and finches were studied by Hayslette pigeons (Hayslette 2006). A. Presotto reported on the possibility of birds' influence on the evolution of wild sunflower species, in particular on hybrid populations (Presotto et al. 2016). These studies concerned wild bird species, which are mainly crop destroyers in some regions. Breeding in this case is forced to go in the opposite direction to reduce the preference of birds for the harvest. To do this, sunflower seeds must be larger to be inaccessible to small birds and have a light colour that, according to our practical observations, scares away wild birds. The results of studies of food preferences of birds in parks and squares are known. Bird feeding is becoming popular and is shaping the birds feed market (Jones and Reynolds 2008).

Feed manufacturers need to know which feeds are most in-demand among birds (Cox and Gaston 2015).

Feeding poultry has its own established patterns, the use of which allows you to quickly gain live weight or eggs. The composition of the feed is important for feeding birds on farms. When comparing, for example, feed on high-protein sunflower meal with soybean meal, improved egg production of chickens was found (Kocer et al. 2021). A high-protein sunflower seed meal is a very valuable product not only for birds but also for humans. For example, the use of this product in the creation of gluten-free bread is better than other protein components, such as peas (Zorzi et al. 2020). From this, it becomes clear the need for selection work to increase the protein content in the seeds, which has already begun, to create a confectionery sunflower (Gholinezhad et al. 2014; Lipeijiang et al. 2017) for the food industry. Such seeds will also be useful in bird feed.

In addition to raising poultry on poultry farms, there are many ornamental pets whose preferences and health greatly anxiety their owners. In this regard, there are many scientific papers (Kaya et al. 2012). Thus, when studying the diet, it was found that sunflower seeds with a high oil content have a very good effect on the development of young parrots, but in adults, feeding only sunflower causes obesity (Saad et al. 2008). Therapeutic diets of parrots showed a better accumulation of drugs in the body with the use of sunflower feed in the husk (Ward 1997). While other researchers have found that processed extruded feed from sunflower seeds, is better than whole seeds (Di Santo et al. 2019). However, for many birds, especially parrots, the most popular food is sunflower seeds (Rachmatika et al. 2019). The solution to the problem of creating food that would meet the preferences of parrots, and at the same time as dietary and therapeutic lies in the plane of breeding opportunities.

The genetics of many components that determine the required qualities of seeds have been studied to varying degrees. The main genes that determine the colour of seeds are established (Gorohivets and Vedmedeva 2016; Poliakova and Vedmedeva 2016; Polyakova 2016; Tolmachev et al. 1990; Tang et al. 2006). To solve the problems of selection with heterogeneous colour selection material, it is possible to use automatic devices for colour determination (Aliiev 2020). The traits content of protein, husk, and oil have been studied in many studies, but all studies indicate complex polygenic control of these traits (Anisimova et al. 2004; Ferfuia and Vannozzi 2015; Leon et al. 2003). According to the size of the seeds, a variety of collections were studied (Gavrilova et al. 2015), polygenic inheritance systems with epistatic action were established (Reinert et al. 2020). The general variety of collections of sunflower lines available in the world, despite the complexity of the combination of many important features, can ensure the creation of a new breeding product but requires a proper search for source material and its involvement in the breeding process.

Namely, it is necessary to select such source material of sunflower which will be able to give not big fat content, sufficient protein content and will have the size and colour of seeds corresponding to preferences of birds. Our research aims to evaluate the available collections by the genetic potential of sunflower seed quality: size, husk colour, oiliness and parental qualities to create a special sunflower suitable for use on bird feed.

Materials and methods

The material for the work was a collection of sunflower lines of the Institute of Oilseeds of NAAS of Ukraine, Zaporizhia. According to the results of previous long-term studies of the collection, groups were identified by the colour of the seed foetus and the inheritance of some of them was studied (Gorohivets and Vedmedeva 2016; Poliakova and Vedmedeva 2016). A set of nine lines of three groups by seed colour was selected: white (VIR130, I2K2218, KG9), grey–white striped (InK1587, InK1039, In18928), grey–yellow–striped (APS33, APS28, APS25), and different seed sizes. For contrast, a line with fine seeds HAR7 with black and grey striped seeds, as a standard, of those used in breeding. The resulting collection was studied separately for three years in a field experiment. We crossed with the available sterile maternal lines, which are used in the selection of oil hybrids sunflower L12A, L14A, LVO12A, ZL72A, ZL169A, ZL42A, ZL78A, ZL90A, ZL50A, ZL70A, SH75A, ZL86A. Seeds of hybrids of the first generation of 2–5 combinations from each parental line were obtained. Hybrids were tested for economic qualities in 2019–2020 in a field experiment.

The field experiment was conducted in the scientific crop rotation of the Institute of Oilseeds of NAAS. The technology of tillage is classical (Аксенов et al. 2013), sowing by hand planters according to the scheme of 70 × 70 cm for two plants in the nest. Four-row plots with an area of 23.5 m^2. Hybrids were studied in triplicate to establish yield from the plot. Determination of seed qualities was carried out in a certified laboratory of the Institute of Oilseeds of NAAS according to the relevant DSTU 7577 (2014). Morphological measurements and descriptions of lines and hybrids were performed in five reps.

The well-known methods of studying the preferences of species of birds feed are related to wild species of birds (Horn et al. 2014). The researchers used wild bird feeders with separate trays for a variety of foods, including sunflower seeds. Feeding time 48 h (Tryjanowski et al. 2018). In our study, the forages (sunflower seeds) were similar in size. Therefore, we considered it sufficient to place them in one common feeder in a layer of one achene. The feeding time of 3 min was selected in several preliminary trials with the expectation that the hen had time to eat about half of the offered portion of seeds. More seeds and longer feeding times result in more feed losses outside the trough. Because chickens, unlike wild birds in the park, are accustomed to periodically raking “trash heaps”.

Due to the lack of information about the preferences of domestic birds for the colour of sunflower seeds, a test study was conducted on domestic chickens. Seven chicken were taken as replicates, which were above fed with compound feeds. Separately, each bird was given a mixture of sunflower seeds of 50 seeds of different types of colour: (1) white; (2) grey–white striped; (3) grey–yellow striped; (4) black and grey striped; (5) light grey colours. The seeds were left for 3 min, the residue was divided by colour and counted. An hour later, the experiment was repeated with the same birds on the same fresh portion of the mixture.

The obtained results are statistically calculated, the averages and errors are determined (Dospekhov 1985).

Results and discussion

The preference of birds for the consumption of seeds, especially domestic ones, has not been studied, although no one denies that they love sunflowers. Our observations of birds and the sunflower seeds they have gnawed in the field in our research sites have shown that wild birds, such as sparrows and tits, eat the striped seeds first, then the black ones, and the white ones only when there is no other.

To confirm the hypothesis about the importance of seed colour for birds, we experimented to study the preferences of birds. Each of the seven selected chickens was separated and then given a mixture of sunflower seeds. The results of the study of bird preferences are presented in Table 1. The calculation of Fisher's test showed the traitificance of differences in the preferences of different foetuses of sunflower seeds by birds. F at the first feeding was 27.34, and at the second 32.99 at standard F = 2.69. When analysing individual groups by seed colour, it was found that birds prefer striped. At the same time, it was best to eat more contrasting in colour stripes of seeds – grey–yellow–striped, and the least – white seeds. They liked the grey–yellow stripe a little more than the grey–white stripe, but in terms of errors, it is very close to their limit. As it turned out, the grey colour was better perceived by birds than completely white, although much worse than striped. Grey seed is a hybrid with a white-seeded parental form, which had a light grey colour due to the transmission of a dark phytomelanin layer through the white epidermis (Figure 1).

Table 1 also provides biochemical parameters of different groups of seeds that were given to birds. Of course, the birds will not be able to assess the quality of the seeds in the mixture, but the presented data show that the quality of the seeds was quite close, except for the grey–yellow striped seeds, which differed greatly in seed size. The size of the seeds probably also contributed to the preference. In our opinion, this indicates that the size of sunflower seeds for chickens is not critical and does not matter as colour.

Based on the results of this study, we decided that striped sunflower seeds with alternating white stripes with black or grey ones will be in special demand in the poultry feed market. Moreover, the seeds must be of different sizes. For small birds, the seeds are small with a weight of 1000 seeds of 20–40 g, and for large birds, larger ones are suitable (Rachmatika et al. 2019). Sunflower seeds with small and striped seeds have already been grown in Ukraine for the production of seed fodder

Table 1: The results of the preferences of chickens sunflower seeds of different colours of the foetus.

Seed colour	Percentage of seeds eaten in 3 min		Weight of 1000 seeds, g	Oil content, %	Protein content, %
	One feeding	Two feeding			
Light grey	19.1 ± 0.88	18.8 ± 1.66	68.4 ± 1.64	40.5 ± 0.63	19.7 ± 0.70
Grey and white striped	23.4 ± 1.02	23.1 ± 1.12	40.2 ± 1.80	43.5 ± 0.60	20.7 ± 0.54
Grey–yellow–striped	24.1 ± 0.82	24.9 ± 0.26	109.8 ± 1.12	37.5 ± 0.71	20.0 ± 0.48
Black and grey striped	19.8 ± 0.88	19.7 ± 0.33	54.2 ± 1.63	35.3 ± 0.90	20.0 ± 0.39
White	16.1 ± 1.54	15.9 ± 1.71	54.2 ± 1.63	39.1 ± 0.64	20.5 ± 0.64

(seed mixtures), although so far in small areas. The second important group to search for is the white-seeded sunflower. It is the least eaten by birds and is therefore likely to have the opposite use – as the most protected from wild birds in crops for human consumption. This uses seeds with a large achene size. In Asian countries, such seeds are already used as a snack. Therefore, for further research, we also identified a group of white-seeded sunflowers.

The involved lines are included in the collection of sunflower lines created by us and submitted for registration by seed colour. Following the studies to determine the genetics of the trait in Table 2 presents a record of the genotype and phenotype of each of them. The genotype was recorded in previous studies (Gorohivets and Vedmedeva 2016; Poliakova and Vedmedeva 2016).

At least three genes are responsible for seed colour, not counting anthocyanin colour genes. The upper layer of the seed – the epidermis may have even pigmentation, be transparent or striped. Lines with the striped epidermis (Estr gene) and white (Ew gene) were selected accordingly. Under the epidermis of the foetus of sunflower seeds may be a phytomelanin layer of black charcoal hue, due to the dominant allele of the P gene. Its absence is due to the recessive state of the gene. Under the phytomelanin is the hypodermis. It can be dark (Hyp allele), snow-white (hypyw allele), or yellowish (hyp allele). As for the shades of the hypodermis, not everything is clear yet, and maybe more alleles and shades. However, in the striped seeds, the presence of yellowish, white, or grey stripes is detected. Therefore, lines of all three stripe colours were included in the

Table 2: Collection of striped and white by the colour of the foetus sunflower lines.

	Colouring of layers of fertilization				ACCENUMB	Name of lines
Group	Genotype			Phenotype		
	Epidermis	Phytomelanin	Hypoderm			
7	EstrEstr	PP	hyp_{yw} hyp_{yw}	Grey and white striped	UE0100504	InК1039
	EstrEstr	PP	hyp_{yw} hyp_{yw}		UE0100718	In18928
	EstrEstr	PP	hyp_{yw} hyp_{yw}	White stripes are larger than grey	UE0100483	InК1587
11	EstrEstr	pp	hyp hyp	Grey–yellow–striped	UE0100940	APS 28
	EstrEstr	pp	hyp hyp		UE0101231	APS 25
	EstrEstr	pp	hyp hyp		UE0100901	APS 33
13	EstrEstr	PP	HypHyp	Black and grey striped	UE0101204	HAR 7
14	Ew Ew	PP	hyp_{yw} hyp_{yw}	White	UE0100605	ВИР130
	Ew Ew	PP	hyp_{yw} hyp_{yw}		UE0100583	I2К2218
	Ew Ew	pp	hyp_{yw} hyp_{yw}		UE0101059	КГ 9

experiment, and the InK1587 line was also selected, in which the white stripes of the epidermis occupied a much larger surface of the achene. In this line, as in many other stripes, there is a different ratio of the area of white and dark stripes even within one head and, accordingly, even more diversity within one line.

In the experiment of 2018–2020, all selected lines were studied for important features for cultivation. The average measurement results are presented in Table 3. The table shows that the lines differed in the growing season and flowering period for almost a month from June 30 to July 28. Among them, there were no short ones, only the usual height for the lines and tall ones (114–150 cm). The foliage was moderate and in the In18928 line even large. It is advantageous for the parent lines to have branching, which gives the advantage of pollination when growing a hybridization site. Therefore, each of the groups of lines had lines with a trait of branching: KG9, InK1039, APS28, HAR7. The diameter of the head in the lines is important for predicting the number of seeds that can be grown, but for parent lines, especially with the presence of branching, the small diameter of the head is not a significant drawback. The detected diameter of the head of lines ranged from 9.8 to 18.8 cm.

The most important indicators for the lines are the quality of seeds, which consists of size (weight of 1000 seeds), oil content, husk. Of all the lines involved, as it turned out, there were no high-oil ones – a maximum of 38.4% in APS33. Most lines had high and very high husks (up to 50%). The crude protein content in the kernel is 22–34%. It was transferred to the protein content in the seeds. And it turned out that in the lines it was from 11 to 20%. Given the arid conditions of growing 20% protein is a fairly high protein indicator. The nutritional value of the seeds of the studied lines: can be defined as 25–38% oil, 11–20% protein, 34–55% carbohydrates and up to 10% water. The mass of 1000 seeds of the line was observed in the range from 20 to 60 g. Moreover, the group of white seed lines with small seeds were not selected. In addition, some of the lines were diagnosed with diseases in some years. This whole description of the lines indicates a fairly low level of the source material. This indicates that it is not possible to use it directly to create hybrids of the required quality. However, this material will be used to create new lines.

For further use, the question arose of obtaining and evaluating the donor properties of the lines. There are few maternal lines with a special colour in the world. Only some stripes (grey–white) are known, but they were not available, so the usual selection of grey–black stripes and phytomelanin. Many lines were used due to different flowering dates. The obtained hybrids were studied on economic grounds. Three to five combinations were obtained with each line.

The colour of seeds of hybrids of the first generation is estimated. The appearance of hybrid seeds and their parental lines are shown in Figures 1, 2, 3, and 4.

Table 3: Morphological features of sunflower lines with striped and white seeds.

Passport No.	InK1039	In18928	InK1587	APS 28	APS 25	APS 33	HAR 7	ВИР130	I2K2218	КГ 9
Flowering time, date	11. July	08. July	05. July	01. July	03. July	11. July	30 June	02. July	28. July	20. July
Plant: at natural height, cm	132.0 ± 10.20	147.6 ± 9.02	128.4 ± 6.49	124.0 ± 6.51	114.6 ± 1.13	123.0 ± 11.14	115.0 ± 1.8	150.4 ± 1.9	129.4 ± 4.70	141.6 ± 0.39
The number of leaves, pcs.	23.8 ± 6.42	34.2 ± 4.60	26.6 ± 3.68	20.4 ± 3.68	21.8 ± 2.96	20.2 ± 2.39	19.4 ± 0.60	21.2 ± 0.60	16.8 ± 1.62	19.4 ± 0.50
The number of branches, pcs.	2.5 ± 1.06	0	0	11.5 ± 4.21	0	0	15.4 ± 0.6	1.5 ± 0.6	0	9.0 ± 0.54
Leaf: length, length, cm	16.2 ± 1.62	22.4 ± 1.42	19.6 ± 1.35	20.1 ± 1.78	13.2 ± 1.13	17.3 ± 2.80	16.6 ± 1.04	14.3 ± 0.52	13.9 ± 0.92	14.8 ± 0.29
Leaf: width, size, cm	19.4 ± 1.42	23.5 ± 1.64	20.7 ± 2.04	18.6 ± 1.42	12.6 ± 0.81	16.4 ± 3.12	15.1 ± 1.40	14.1 ± 0.68	12.8 ± 2.18	15.8 ± 0.23
Petiole length, cm	11.8 ± 2.22	16.6 ± 0.68	11.0 ± 1.24	10.4 ± 1.88	9.6 ± 2.57	11.6 ± 2.42	10.4 ± 0.50	8.0 ± 0.36	10.6 ± 3.35	7.7 ± 0.16
Diameter of a basket, see	14.3 ± 0.43	18.8 ± 0.38	18.4 ± 1.72	11.0 ± 0.71	11.7 ± 0.43	17.1 ± 0.50	10.3 ± 1.3	17.4 ± 0.23	9.8 ± 1.22	12.4 ± 0.27
Seed oil content,%	19.1 ± 1.04	20.5 ± 1.84	25.5 ± 1.78	31.4 ± 1.24	25.6 ± 1.43	38.4 ± 1.99	34.5 ± 1.48	27.8 ± 1.29	24.9 ± 1.24	32.9 ± 1.82
Protein content in seeds,%	15.7 ± 1.6	11.2 ± 1.3	18.1 ± 1.8	16.0 ± 0.6	19.9 ± 0.9	18.0 ± 1.2	20.9 ± 0.8	17.6 ± 0.9	20.75 ± 1.1	13.2 ± 0.9
Weight of 1000 seeds, g	38.5 ± 2.74	43.1 ± 2.09	47.4 ± 2.45	20.3 ± 1.47	49.7 ± 1.24	39.0 ± 1.37	54.6 ± 2.31	60.1 ± 5.27	52.3 ± 1.81	50.9 ± 7.21
Husk,%	38.6 ± 9.06	50.9 ± 10.00	42.1 ± 9.37	30.9 ± 8.61	43.1 ± 9.21	32.4 ± 8.43	22.4 ± 7.16	34.8 ± 8.35	30.33 ± 8.46	42.9 ± 8.92
The presence of diseases	Phoma, alternaria	Rust, alternaria			Alternaria			Phoma	Phoma	

The errors of the indicators are indicated after the trait ±.

In Figure 1, all three parental lines had a white colour of the husk on visual perception. Seed colour of hybrids with lines VIR130 and In2K2218 had hybrids with white seeds. In both cases, there was a dark layer of armour under the white layer. In different hybrids, the colour had a different shade of grey, which was due to the different transparency and thickness of the upper white layer. Probably the thickness of the epidermis (or its dense colour) have a separate genetic condition and are controlled by several factors. Thus, hybrids with the VIR 130 line had completely white seeds. This line also had a phytomelanin layer, but it did not shine through in hybrids. When removing the upper white layer in both cases in hybrids, as in the line was found below the dark phytomelanin layer. The KG9 line had a uniform white colour, but its hybrids turned out to have a dark colour of seed, namely intense anthocyanin (purple). This indicates the presence of another version of the combination of colour genes. Namely, the presence of anthocyanin staining, which is controlled by two or three genes (Leclercq 1968; Mosjidis 1982) in this case combined the genes of the parental forms and caused the anthocyanin staining.

Figure 2 shows the lines with the grey–white striped colour of the seeds and their hybrids. In the line, InK1587 was a hybrid, as well as combinations above, with anthocyanin colour and, accordingly, white stripes were absent. In the other two lines In18928 and InK1039, the main T gene, which causes the presence of anthocyanin, was in a recessive state and, accordingly, the colour of the hybrid seeds remained striped. The distribution of bands in individual hybrids and heads differed, sometimes quite markedly, but had a great variety even within a single head.

Figure 3 shows the lines with the grey–yellow striped colour of the seeds APS33, APS28 and APS25 and their hybrids. As it turned out, the hybrids had an almost normal colour with a dark phytomelanin layer and grey stripes. This indicated the presence of striated epidermis, which consisted of stripes of its absence and light grey stripes.

Figure 4 shows the HAR 7 line, with the usual dark striped colour, hybrids with it were respectively the same colour.

The obtained experimental hybrids were studied on economic grounds. The timing of flowering, restoration of pollen fertility, plant height, the diameter of heads, the presence of branching, seed yield, the weight of 1000 seeds, oil content, husk, protein in the seeds were set. In the presence of pollen fertility restoration genes to the normal breeding sterile line, only HAR7 and InK1039 lines have pollen fertility restoration genes. The onset of flowering of most hybrids was within one week – quite early, medium – a week later hybrids with lines APS33 and In18928 bloomed. Branching in the APS 28 line was dominant and manifested in 100% of hybrid plants. The main anthocyanin gene of T disk flowers (and anthocyanin in

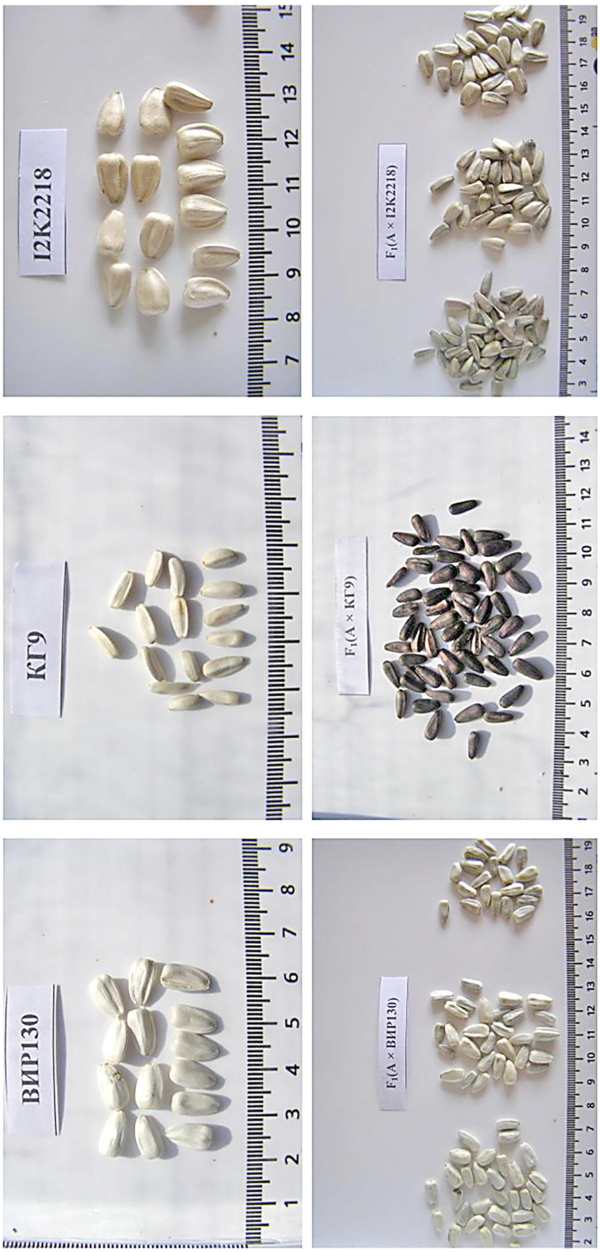

Figure 1: Colouring of seeds of parental lines of sunflower of group 14 and their hybrids.

Figure 2: Colouring of seeds of parental lines of sunflower of group 7 and their hybrids.

Figure 3: Colouring of seeds of parental lines of sunflower of group 11 and their hybrids.

Figure 4: Colouring of seeds of the parental line HAR7 of sunflower of group 14 and its hybrids.

other parts of the plant) in the dominant state present in the parental lines VIR130 and KG 9 was found in hybrids with them.

Three hybrids in three replicates were evaluated for each line. To assess the parental properties of the lines, the obtained indicators were averaged and presented in Table 4. The obtained average yield of hybrids in most lines was quite high, given the very arid conditions of 2019–2020. There was more precipitation in 2020, but a large amount of it during growth did not form a deep root system of sunflower. And the lack of precipitation from the beginning of flowering and during ripening – led to low seed yield and weight of 1000 seeds. Accordingly, the yield of 3.05 t/ha of hybrids with the VIR130 line is a very good indicator. However, since the lines cannot be used directly in hybrids, it is not advisable to determine their combination ability.

Hybrids with lines: I2K2218, VIR130, In18928, ARS 25 showed the weight of 1000 seeds more than 60 g. The first two lines I2K2218, VIR130 weighted 1000 seeds of 52 and 60 g, respectively. This indicates good donor properties in terms of seed size, which is relevant due to the white colour of the husk of these lines. The oil content of the studied hybrids was quite low 35–44% and the protein content was also from 11 to 16%. The most informative is the trait of husk in the hybrid because it is due to the genotype of the hybrid and does not depend on the genotype of the pollinator. Hybrids with KG9 lines (28% in hybrids and 42 in the line), In18928 (27.7% in hybrids and 50% in the line) kept such high husk of parental forms. Other lines formed the husk of hybrids at the level of 20–26%.

The height of hybrid plants also depended on the genotype of the parental lines. Thus, the highest parental lines VIR130 and In18928 had the highest hybrids 210–184 cm. Therefore, to improve the quality of the lines, the difference in plant height of the lines of 20 cm can significantly increase the height of hybrids in the absence of dominant short stature genes.

Table 4: Average test scores of test sunflower hybrids with collectable parent lines.

The parent line of the hybrid	Yield, t/ha	Weight of 1000 seeds, g	Oil content, %	Protein content in seeds, %	Husk, %	Plant height, cm	Diameter of the head, cm
ARS 25	2.04 ± 0.16	62.7 ± 1.20	44.2 ± 11.0	14.20 ± 1.05	24.1 ± 2.3	148 ± 2.36	19.6 ± 0.46
APS 28	1.96 ± 0.08	43.5 ± 2.78	44.5 ± 0.09		23.5 ± 2.1	161.0 ± 3.7	13.8 ± 0.62
APS 33	1.76 ± 0.08	47.4 ± 1.37	43.5 ± 0.60	12.93 ± 1.03	22.8 ± 2.5	144.6 ± 3.6	17.2 ± 0.63
In18928	2.61 ± 0.12	68.9 ± 3.95	35.1 ± 1.55	12.16 ± 0.57	27.7 ± 2.3	184.3 ± 7.32	18.9 ± 0.92
InK1039	1.82 ± 0.06	41.2 ± 1.14	37.5 ± 0.71	16.11 ± 0.08	23.9 ± 3.6	170.1 ± 2.19	21.2 ± 0.14
InK1587	2.20 ± 0.35	43.7 ± 2.44	43.1 ± 2.18		26.4 ± 3.3	153.9 ± 7.99	16.4 ± 0.53
ВИР130	3.05 ± 0.07	65.0 ± 4.30	39.1 ± 0.64	13.73 ± 0.10	24.8 ± 2.9	210.7 ± 6.43	20.4 ± 1.03
КГ9	2.43 ± 0.26	45.6 ± 3.27	44.2 ± 1.89	11.08 ± 0.89	28.4 ± 4.2	160.8 ± 6.65	20.4 ± 1.56
I2K2218	2.68 ± 0.17	62.2 ± 3.85	40.5 ± 0.63	15.94 ± 4.64	20.6 ± 1.1	184.4 ± 3.43	20.1 ± 0.44
HAR7	1.64 ± 0.05	57.9 ± 1.30	35.3 ± 0.90	13.55 ± 1.04	26.3 ± 4.2	155.2 ± 5.55	18.5 ± 0.83

The evaluation of the source material of the lines for further use should be summarized by colour groups. Thus, in the 11th group of lines (Table 2) which had stripes of brown–grey and yellow and did not have a phytomelanin layer of three lines APS 33, APS 28, APS 25, there was no pollen fertility restorer. The most interesting was the line APS 28, which was early ripening, had branching and with small seeds gave a decent yield of the hybrid. For its use, it is necessary to include it in crossing with maternal sterility fixers with striped seeds (grey–black) and available armour, preferably high in protein.

The seventh group of lines In18928, InK1039 and InK1587 is the most promising for use in birds. Of these, the InK1039 line contains pollen fertility and branching genes, but to use it to create a pollen fertility restorer, it must be included in a cross with a reducing agent that will have a striped seed colour (grey–black), early maturity, preferably with short stature and disease resistance. The other two lines, In18928 and InK1587, can be used to create parent lines, but have high husks. InK1587 was relatively resistant to major diseases.

From the 14th group I2K2218, KG9, VIR130 all three lines can be used for the creation of food hybrids with the white colouring of seeds. KG9 line in creating a pollen fertility restorer, giving it resistance to diseases, short stature, protein content. And lines I2K2218, VIR130 can be included in the creation of pollen fertility fixers with the obligatory addition of resistance to disease, lodging and early maturity.

Our results on the preference of dark-coloured sunflower seeds over light-coloured chickens confirm the results of studies carried out on wild birds: doves (Hayslette 2006) and chickadees (Horn et al. 2014; Johansen et al. 2014). However, our research indicates a preference for seeds with contrasting stripes over all other colours. In addition, we examined chickens, not wild birds. We are not aware of any publications in which such colours have been studied. It has been established that our collection has a sufficient diversity of genotypes to satisfy the request for the creation of special use sunflower. Such a sunflower seed market already exists (Orros and Fellowes 2015). Therefore, the results of the research will help in the creation of new sunflower hybrids and new formulations of feed for domestic and wild birds.

Conclusions

The preferences of birds for the colour of sunflower seeds have been established. Domestic chickens like contrasting striped seeds with white and dark stripes, and the least white colour of the seeds. Accordingly, to create sunflower hybrids for use in food birds need to use striped lines of the collection, and to protect against wild birds lines with white seeds.

Studies show that to create a hybrid of poultry feed in the form of whole seeds, it is necessary to use the InK1039 donor stripe and small seed size to create a pollen fertility restorer. In creating the maternal line, it is better to use InK1587 – a donor of striped seed colour and early maturity. It is also possible to use the APS 25 line as a donor of the same traits, but with mandatory crossing with the armoured line and selection for this trait. To create hybrids with white seeds for human consumption and therefore more resistant to eating by wild birds, you can use donors of white colour of seeds KG9 in pollen fertility resistant and I2K2218 in sterility fixer.

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