Selection of corn hybrids ensuring the production of high-energy feed for modern dairy farming

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Abstract. The "line" of hybrids recommended by the Ural Research Institute of Agriculture Ob 140 SV (FAO 140), Ross 130 MV (FAO 130) and Kuban 101 SV (later Kuban 102 SV) (FAO 120) in 2016...2020 occupied 81.8...90.6% in the structure of sown seeds in the Sverdlovsk region. The area under corn by 2014 increased to 19.39 thousand hectares (6.3 times compared to 2008) and in 2015...2020 it stabilized at the level of 19.3...21.0 thousand hectares. The production test of the "grain" corn cultivation technology developed by the Ural Research Institute of Agricultural Sciences was carried out in four basic farms, in which the area of corn sown increased by 1.9 times over the period from 2012 to 2020, with a simultaneous increase in the sowings of high-protein crops: alfalfa and oilseeds. In the agricultural organizations of the SEC "Kilachevsky" and the SEC named after. The starch content in the silo reached 202-364 g/kg in 2017...2020, in some years it decreased to 142...146 g/kg (SEC "Kilachevsky") and to 64...67 g/kg (SEC im. Zhukov). Over the past 3...5 years, individual farms of the region have begun to harvest cornage from corn. In the SEC "Kilachevsky", the starch content in the new type of feed was 247 g/kg SV in 2018, 341...407 g/kg in 2019 and 439 g/kg SV in 2020. The research was carried out on the basis of the FSBSI URFANITS UrB RAS as part of the State Task on the topic "Creation and improvement of adaptive technologies for the cultivation and processing of economically significant agricultural crops based on the optimization of biotic and abiotic factors".

1 Introduction

In the first years of corn introduction in the Urals, a number of scientists proved the feasibility of growing varieties and hybrids with a period of germination - wax ripeness of 95-100 days, which gave high yields of dry mass with ears of milk-wax ripeness [1, 2, 3]. N.N. Zezin, A.E. Panfilov, N.I. Kazakova et al. (2017) note that in the southern regions of Russia, it was not possible to develop seed production of early-maturing varieties and hybrids of corn adapted in the Urals. The seeds of late-maturing hybrids continued to be supplied in the Sverdlovsk Region, reaching the tasseling phase - ear flowering, by harvesting. As a result, the dry matter

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content in the green mass during the harvest period was very low (10...15 %). To solve this problem, the task was set to select corn hybrids with FAO 120...150, which reach the phase of grain milk-wax ripeness by harvesting, providing a high starch content in the dry matter of silage and cornage.

2 Materials and methods

The research was carried out in field experiments at the Koltsovsky site of the Ural Research Institute in 2012...2020. The weather conditions were different: the hydrothermal coefficient of the period May...September was 1.24 in 2012, 0.81 in 2016, and reached 2.13 in 2015, with an average annual value of 1.57. Farm tests of the developed "grain" technology of corn cultivation were carried out in four basic farms of the Sverdlovsk region: SEC "Kilachevsky", SEC n.a. Zhukov, JSC "Agrofirma "Patrushi", LLC "Nekrasovo 1".

3 Results and discussion

Studies of many scientists have found that during the maturation of corn plants, the ratio of nutrients changes: the content of dry matter and starch increases to the full ripeness phase, but the content of sugar and raw protein decreases. According to D. Shpaar et al. (2009), by the time of flowering, the starch concentration in the dry matter reaches 2 % and only by the end of the milk ripeness – beginning of the wax ripeness increases to 14...22 %. In the experiments of the Ural Research Institute of Agriculture, the chemical analysis of plants showed that the main part of starch is contained in corn grain (Table 1).

Table 1. Starch content in various organs of corn plants, % (2011...2013).

No.	Hybrid	FAO	Grain	Leaf	Stem
1	Kubansky 101 SV	120	75.2	4.20	4.36
2	Ross 130 MV	130	74.4	3.44	4.19
3	Omka 130	130	74.0	3.02	4.21
4	Kubansky 141 MV	140	73.2	2.50	3.06
5	Obsky 140 SV	140	72.7	2.64	2.89
6	Mashuk 150 MV	150	71.7	2.56	2.91
7	Omka 150	150	71.4	2.57	2.77
8	Katerina SV	170	70.0	2.15	2.57
9	Mashuk 170 MV	170	70.0	2.40	2.68
10	Ross 140 MV	180	68.2	1.91	2.32
11	Klifton	180	69.0	2.24	2.57
12	K 180 SV	190	66.8	2.04	2.40
	On average		71.4	2.64	3.08

In the grain of hybrids with the FAO index of 120...140 (Kubansky 101 SV, Ross 130 MV, Omka 130, Kubansky 141 MV, Obsky 140 SV), the starch content was the highest (72.7...75.2 %), and in Klifton hybrids (FAO 180) and K 180 SV, it was 69.0 and 66.8 %. On average, of the 12 hybrids studied, the starch content in the grain was 71.4 %, in the leaves - 2.64 %, in the stems – 3.08 %. In studies of 10 samples of 2018...2019, the starch content in dry grain ranged from 70.4 to 75.1 % [6].

Thus, the feed qualities of corn are largely determined by the amount of dry matter and starch in the ears and their proportions in the dry matter of the whole plant. The higher the dry matter content in corn plants, the more energy is contained in the finished feed.

Long-term research of the Ural Research Institute of Agriculture for the selection of hybrids adaptive to local conditions, working out the "grain" technology of their cultivation to obtain high-quality silage and cornage has shown that the productivity of corn depends mainly on the early ripeness of hybrids, the timing of sowing, the timing of harvesting and the weather conditions of the year. Thus, in 2010, with the sum of positive temperatures for May...September 2355ºC (the average annual norm of 2042ºC) when sowing on May 16 and harvesting on September 16, the dry matter content in the green mass was 40.4% in the hybrids Obsky 140 SV, Kubansky 101 SV-41.8 % when collecting dry matter, respectively, 15.1 and 10.5 t/ha. The hybrid Obsky 140 SV provided the largest starch harvest (4.61 t/ha) when sown on May 15, and the early-season hybrid Kubansky 101 SV - when sown on May 25 (3.59 t/ha).

In 2016, when the sum of positive temperatures for May...September was 2420˚C, in the best variants, the collection of dry matter reached 16.8 t/ha, and the yield of starch from 1 ha was 5.2 t.

In less favorable 2011, the sum of positive temperatures for V...IX was 2205ºC, dry matter content in green mass by mid-September (13.09) reached in hybrids: Katerina SV 23,3 %, Obsky 140 SV – 28,5 %, Kubansky 101 SV – 34,0 %, and by the end of August (30.08) equaled 19,2; 23,0; 28.1 %. The starch content of the Kubansky 101 SV hybrid was the highest and increased from harvesting on August 30 (12.4 %) to September 14 (28.7%). The lowest indicators were found in the hybrid Katerina SV - 4.72 and 14.8 %.

The creation of the SE "Union of Seed Growers of the Urals" at the Ural Research Institute of Agriculture in 2008 contributed to the expansion of crops of early-season hybrids with FAO 120...140. The Ural Research Institute of Agriculture and SE "Union of Seed Growers of the Urals" jointly developed recommendations for the supply of corn seeds of adapted hybrids, based on annual environmental tests of hybrids, field experiments on improvement of "grain" technology of corn cultivation for silage and cornage. The farm test of the developed technology was carried out in different weather conditions in the basic farms (SEC "Kilachevsky", SEC n.a. Zhukov, CJSC "Agrofirma "Patrushi", LLC "Nekrasovo 1").

In 2011, 95.4% of all corn seeds supplied to the region were the Katerina SV hybrid (FAO 170) and only 3.8% - the Obsky 140 SV hybrid (FAO 140). By 2015, the share of seeds of the Katerina SV hybrid supplied to the Sverdlovsk region decreased to 26%, and the Obsky 140 SV hybrid increased to 70.5 %. In parallel, the study of individual elements of the technology of more early-season hybrids cultivation – Kubansky 101 SV (FAO 120) and Ross 130 MV (FAO 130) was carried out.

As a result of many years of research and farm testing of hybrids and techniques, a "line" of hybrids of various ripeness was determined, providing a conveyor supply of green mass with ears of milk-wax grain ripeness. For the early sowing period (May 10...15), the hybrid Obsky 140 SV (FAO 140) is recommended, for the second term (May 15...20) – Ross 130 MV (FAO 130) and for the third sowing period (May 20...25) – Kubansky 101 SV. A distinctive feature of the Kubansky 101 SV hybrid was the low attachment of the ears during early sowing (35...45 cm) and not a large height of the plants for harvesting (165...170 cm), with later sowing these indicators increased to 50...60 cm and 180...210 cm.

The analysis shows that in the structure of corn seeds sown in the Sverdlovsk region in 2016...2020, hybrids recommended by the Ural Research Institute of Agriculture with FAO 120...140 occupy the largest share – from 81.8 to 90.6 % (Table 2). Over 5 years, the share of the Obsky 140 SV hybrid has decreased by 2 times (from 52.5 to 25.5%). At the same time, the volumes of sown hybrids with FAO 120...130 significantly increased: Ross 130 MV from 29 to 40.9 %, Kubansky 101 SV from 2.1 to 15.4 %.

Table 2. The share of corn hybrids recommended by the Ural Research Institute of Agriculte in the total volume of sown corn seeds (according to the data of the FSBI "Rosselkhozcenter"), %.

Hybrid	FAO	Year				
		2016	2017	2018	2019	2020
Obsky 140 SV	140	52.5	48.2	48.1	31.3	25.5
Ross 130 MV	130	29.0	22.3	38.9	46.3	40.9
Kubansky 101 SV	120	2.1	6.6	2.9	13.0	15.4
Total for three hybrids		83.6	77.1	89.9	90.6	81.8
Total hybrids sown, pcs.		15	11	12	9	15

Thus, in a very short period in the feed production of the Sverdlovsk region, there was a radical change in the structure of forage crops. In 1950...1960, corn crops reached 150...180 thousand hectares, on average for 1971...1975, it occupied 117 thousand hectares, in 1986 – 94, 1987 – 88 thousand hectares. In subsequent years, the acreage of corn was rapidly declining and amounted to 5.69 thousand hectares in 2006, 3.36 in 2007; in 2008 – 3.09 thousand hectares. With the supply of seeds of mainly early-season hybrids to the region with FAO 120...150, the area under corn by 2014 increased to 19.39 thousand hectares (6.3 times compared to 2008). In 2015...2020, the acreage of corn grown using "grain" technology stabilized at the level of 19.3...21.0 thousand hectares.

It is noteworthy that in recent years, along with corn, crops of high-protein crops - alfalfa and oilseed crops (rapeseed, summer rape, flax) have become in demand and are increasing in the farms of the region (Table 3). All these crops, characterized by a high content of energy and protein, have a high drought resistance. The availability of such crops should also be expanded due to the fact that three years have been acutely arid over the past 10 years.

Table 3. Acreage of high-energy, high-protein crops in the Sverdlovsk region (according to the data of the Ministry of Agro-industrial Policy and Food of the Sverdlovsk region, 2011...2020), ha.

Crop	Year						
	2011	2015	2016	2017	2018	2019	2020
Corn	8.7	20.2	19.3	21.0	20.9	19.9	21.0
Alfalfa	11.7	22.3	20.8	19.4	23.0	33.7	37.6
Oilseed crops (rapeseed, summer rape, flax)	9.8	21.7	23.6	27.7	30.8	27.3	22.3
Total	30.2	64.2	63.7	68.1	74.7	80.9	80.9

The improvement of the structure of forage crops contributed to the rapid growth of dairy productivity. In 1987, for the first time, the Sverdlovsk region has become one of the 28 regions of the country that have achieved receipt of more than 3000 kg of milk from a cow per year. It took 20 years to increase milk productivity by 1 thousand kg from one cow (in 2006...2008, milk yield per cow ranged from 4119 to 4208 kg). In 2010, milk production per 1 cow increased to 5160 kg, in 2015 – 6381 kg, in 2020 - to 7876 kg.

Basic farms of SEC "Kilachevsky", LLC "Nekrasovo 1", CJSC "Agrofirma "Patrushi", SEC n.a. Zhukov, where the research was conducted, have the best herds of black-and-white cattle in the Russian Federation in terms of milk productivity (Table 4).

Table 4. Dynamics of milk yield per forage-fed cow in basic farms, kg.

Organization	2012	2017	2018	2019	2020
SEC "Kilachevsky"	8494	10787	11493	11963	12524
CJSC "Agrofirma "Patrushi"	8885	9158	9299	9677	10646
SEC n.a. Zhukov	6745	8604	8790	8914	10127
LLC "Nekrasovo 1"	7385	10419	10570	10583	10835

This is largely the result of a significant increase in the area of corn crops in these farms in recent years (Table 5). On average, for four agricultural enterprises, it increased from 375 hectares in 2012 to 700 hectares in 2020, or by 1.9 times. At the same time, the ratio of corn crops and annual grasses was 1:1.7 in 2012, and by 2020 it was 1:1.

Table 5. The crop structure of the main fodder crops in farms with high milk productivity, 2012 and 2020 (according to the data of the Ministry of Agro-industrial Policy and Food of the Sverdlovsk region).

Year	Corn		Annual grasses		Perennial grasses	
	ha	%*	ha	%*	ha	%*
SEC "Kilachevsky"						
2012	676	12.7	1109	20.9	3411	64.2
2020	1204	17.6	1594	23.2	4061	59.2
LLC "Nekrasovo 1"						
2012	250	11.8	494	23.4	1252	59.2
2020	607	16.2	623	16.6	2523	67.2
CJSC "Agrofirma "Patrushi"						
2012	450	13.6	962	29.2	1789	54.3
2020	588	23.3	566	22.4	1373	54.3
SEC n.a. Zhukov						
2012	125	7.8	0	0	1470	92.2
2020	399	20.1	166	8.4	1423	71.5
Average for four farms						
2012	375	12.5	641	21.4	1980	66.1
2020	700	18.5	737	19.5	2345	62.0

Note: * - the specific weight in the structure of the main forage crops (corn, annual and perennial grasses).

Considering the low protein value of corn mass, farms also increased the acreage of crops with a high protein content: alfalfa and oilseed crops. Moreover, the ratio of these crops in farms is different. For example, in 2020, 0.7 hectares of alfalfa and 1.5 hectares of oilseed crops (rapeseed) accounted for 1 ha of corn in the SEC "Kilachevsky", while 1.5 hectares of alfalfa and 0.45 hectares of rapeseed accounted for LLC "Nekrasovo 1". In the SEC n.a. Zhukov, the ratio of corn, alfalfa and rapeseed was equal to 1:1:0.75.

Thus, the expansion of sowings of corn hybrids with FAO 120...140, recommended by the Ural Research Institute of Agriculte, contributed to improving the quality of the feed base, increasing the milk productivity of the dairy herd. This is clearly seen in the example of basic farms, which in different weather conditions, along with harvesting high-quality silage, began to prepare a new type of feed - cornage with an even higher content of metabolic energy and starch.

In the SEC "Kilachevsky" in 2017, 2018 and 2020, the dry matter content in corn silage ranged from 258 to 364 g/kg (Table 6).

Table 6. The quality of corn silage from various hybrids in the SEC "Kilachevsky".

Indicator	Meas. unit	2017			2018	2020
		Kubansky 101 SV	Obsky 140 SV + Ross 130 MV	Obsky 140 SV + Ross 130 MV	Obsky 140 SV + Ross 130 MV	Obsky 140 SV + Ross 130 MV
Dry matter (DM)	g/kg	364	258	272	267	339
Metabolic energy (ME)	MJ/kg DM	11.6	9.9	9.8	10.3	11.1
Crude protein	g/kg DM	75	83	76	89	89
Raw fat	g/kg DM	34	30	26	37	34
Raw fiber	g/kg DM	156	259	260	231	189
Starch	g/kg DM	382	142	146	193	286

This indicator turned out to be the highest when laying a silo from the Kubansky 101 SV hybrid (FAO 120). There was also the highest starch content – 382 g/kg of dry matter (DM). In other storages, the starch content was 142...286 g/kg DM. In storages No. 8 and No. 12 (2017), the low starch content (142...146 g/kg DM) corresponded to lower indicators for exchange energy (9.8...9.9 MJ/kg DM versus 10.3...11.6 MJ/kg DM in other storages).

In the SEC n.a. Zhukov the highest content of dry matter in corn silage (282...344 g/kg) was noted in 2017, 2019, 2020 (table 7). In these variants, the starch content reached 202 ... 275 g/kg DM.

Table 7. The quality of corn silage from various hybrids in the SEC n.a. Zhukov.

Indicator	Meas. unit	2017		2018			2019		2020
		Ross 130 MV	Obsky 140 SV	Ross 130 MV	Ross 130 MV	Kubansky 101 SV + Ross 130 MV	Kubansky 101 + Ross 130 MV	Kubansky 101 SV + Ross 130 MV	Ross 130 MV
Dry matter (DM)	g/kg	313	282	230	234	249	291	295	344
Metabolic energy (ME)	MJ/kg DM	10.8	10.2	9.7	9.4	9.9	10.6	10.7	10.7
Crude protein	g/kg DM	77	79	96	96	90	82	70	79
Raw fat	g/kg DM	31	26	23	25	28	25	26	42
Raw fiber	g/kg DM	204	245	272	283	259	218	215	207
Starch	g/kg DM	275	206	64	67	136	238	255	202

In 2018, the dry matter content in the silo was less (230...249 g/kg) and the feed in these storages was characterized by a lower starch content (64...136 g/kg DM).

Based on the data in Tables 6 and 7, we can note a tendency to increase the concentration of raw fiber in the silo, reduce the indicators for raw fat and metabolic energy in variants with a lower starch content.

Over the past 3...5 years, individual agricultural enterprises have begun to harvest cornage from corn. In 2019, SEC "Kilachevsky" harvested cornage from the entire area of corn (hybrids were sown with FAO 120...140 Kubansky 101 SV, Ross 130 MV, Obsky 140 SV). The dry matter content ranged from 322 to 351 g/kg, starch in the dry matter - from 341 to 407 g/kg (Table 8). In 2020, the dry matter content in the silo reached 431 g/kg in the SEC "Kilachevsky", 490 g/kg in the CJSC "Agrofirma "Patrushi", and the starch concentration was 439 and 512 g/kg DM, respectively.

Table 8. The quality of corn cornage in the farms of the Sverdlovsk region.

Indicator	Meas. unit	SEC "Kilachevsky"					SEC n.a. Zhukov			JSC "A/f "Patrushi"
		2018	2019			2020	Kubansky 101 SV + Ross 130 MV	Ross 130 MV	Kubansky 101 SV	Ross 130 MV + Obsky 140 SV + Mashuk 140
		Obsky 140 SV + Ross 130 MV	Kubansky 101 SV	Obsky 140 SV	Ross 130 MV	Obsky 140 SV + Ross 130 MV				
Dry matter	g/kg	294	341	322	351	431	403	397	378	490
Metabolic energy	MJ/kg DM	11.6	12.1	11.9	11.9	12.1	11.6	12.1	11.9	12.2
Crude protein	g/kg DM	98	84	81	80	82	74	100	84	99
Raw fat	g/kg DM	31	48	36	32	38	31	37	34	40
Raw fiber	g/kg DM	199	180	178	144	134	160	133	184	95
Starch	g/kg DM	247	341	343	407	439	382	397	310	512

Thus, the experience of advanced farms in the Sverdlovsk region proves the possibility of preparing corn hybrids with FAO 120...140 and silage and cornage with a high concentration of metabolic energy, starch and fat in dry matter.

It should be emphasized that domestic breeders are actively working on creating hybrids for new areas of corn sowing - north and east of the southern traditional zone. Academician of the Russian Academy of Sciences V.S. Sotchenko, Yu.V. Sotchenko, N.A. Orlyansky et al. (2017) report that in recent years, the FSBSI All-Russian Research Institute of Maize has been paying special attention to the creation of hybrids with FAO 130...150. Results of variety testing of early-maturing hybrids in 2016 (Yu.V. Sotchenko, E.F. Sotchenko, E.A. Konareva, 2017) showed that in the group of hybrids (FAO 130), 5 hybrids were identified, more productive and taller in comparison with the Kubansky 101 SV standard. V.S. Sotchenko, A.E. Panfilov, A.G. Gorbacheva et al. (2021) indicate that for the northern zone of corn sowing, selection for a short growing season should be considered as a priority feature when creating adapted hybrids. According to American scientists [10], the development of drought-resistant corn hybrids is important in a changing climate.

Research on the ecological testing of early-maturing hybrids, started in 2008...2010, is continuing at the Ural Research Institute of Agriculture. In 2019 and 2020, the highest dry matter content in the green mass was observed in the hybrid Kubansky 102 SV 35.3 and 32.6 %. The share of ears in the dry matter reached 43.0 and 49.5%, respectively. In 2019, in a farm test on the fields of JSC "Agrofirma "Patrushi", the starch content in the ears was the highest in the hybrids Kubansky 102 SV 59.59%, Ross 130 MV – 50.05 %. In 2019...2020, new hybrids K-140, Ross 125 and others were also studied in the basic farms.

4 Conclusions

The expansion of crops of corn hybrids with FAO 120...140, recommended by the Ural Research Institute of Agriculture, contributed to improving the quality of the feed base and, accordingly, increasing the milk productivity of the dairy herds of the Sverdlovsk region. The recommended "line" of corn hybrids, consisting of Kubansky 102 SV, Obsky 140 SV, and Ross 130 MV, continues to be improved on the basis of both field experiments and scientific and farm tests.

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