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Research article

Maize hybrid productivity and grain quality in conditions of the Cis-Ural forest-steppe

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Abstract: This study (2016–2017) was conducted to identify highly productive maize hybrids for the conditions of the Bashkortostan Republic. Maize growth, yield and grain quality was examined on different hybrids that gave 3.79–5.55 t/ha of maize. Nur and Baikal hybrids showed the best grain quality indicators on the starch content being 61.7% and 60.8%, respectively. From mid-early hybrids Newton, Mashuk 220 MV and Mashuk 250 SV are recommended for silage production.

Keywords: maize; hybrid; plant growth; yield; grain quality

1. Introduction

Until recently in the Republic of Bashkortostan maize has been cultivated for the green mass to prepare silage and feeding farm animals. They selected maize varieties and hybrids, developed cultivation technologies to get green mass [1–6]. However, the green mass of maize, consisting mainly of stems and leaves, usually contains up to 88–90% water. Silage being prepared from such a mass has less dry matter, especially protein. Such feed is of low nutritional value and has relatively low return for livestock products. The most high-quality and nutritious feed can be obtained from maize grain or ground mass with a grain of milk-wax and wax ripeness. 1 kg of maize contains 1.34 feed units and 78 g of digestible protein. Maize is a warm-weather crop. Warm weather is the main limiting natural resource to get its grain on the territory of the Republic. The sum of active temperatures (for the period with the average daily temperature above 10 °C) in the territory of the Republic of Bashkortostan is 900–2300 degrees depending on the zone [7]. Breeders have created a number of early-maturing hybrids that do not require a large amount of heat for grain ripening related to the choice of early-ripening maize hybrids adapted to the agro-climatic conditions of the region of the Republic is one of the important factor to produce high-quality animal feed [8–11].

Maize for silage is harvested in the phase of wax ripeness. Maize for grain is cropped in the phase of full ripeness at humidity of 25% or lower [12–19]. Hybrids of one ripening group can significantly vary in these characteristics due to different rates of moisture loss during maturation. It makes possible to conduct selection according to the accelerated water-yielding capacity. Crop productivity ratio according to the sowing time depended on the climatic conditions in test stations and the weather conditions in separate years. In the All-Russian Maize Research Institute a statistically significant advantage in crop productivity was found. It was based on a three-year research with the optimal sowing period compared to the early sowing time. There were exceptions for hybrids Katerina SV, Mashuk 175 MV, Mashuk 250 SV and Mashuk 350 MV in 2014 as well as for Nur, Mashuk 175 MV and Mashuk 250 SV in 2015. They weren't affected by the sowing time [6,19].

To produce maize grain in the Northern regions of Russia it is necessary to develop ultra-early and cold-resistant hybrids that can withstand the soil temperature below the biological minimum for a long time. In the Northern zone of maize sowing, more attention should be paid to the seed quality. Using seeds with low laboratory germination and spread resulted from their long-term storage can prevent the planned population, delay the seedling emergence. It leads to a weak initial growth of plants and, consequently, to lower yields of grain. To get higher yields with a given population at the optimum sowing time it is necessary to increase the seeding rate by 10–20% in conditions of the Maize Research Institute, by 20–30% in the Chelyabinsk region depending on the hybrid used. It is necessary to take into account the biological characteristics of maize hybrids to germinate in different conditions, seed reproduction, sowing qualities and the seeding rate adjusted to specific growing conditions. Maize hybrid Nur turned to be the best hybrid to be grown for grain at earlier sowing time in conditions of the forest-steppe in the Chelyabinsk region. The stalk fragility below the cob is largely determined by the hybrid's genotype and growing conditions. Cob infection with *Fusarium* varies differently from year to year. However, maize hybrid Nur is found to be resistant to this disease independently of other factors [4].

Thus, the aim of our research was to study the formation of yield and grain quality of corn hybrids in the conditions of the cis-Ural forest-steppe.

2. Materials and methods

Field experiments were conducted at the scientific training center of the Bashkir State Agrarian University. The soil cover of the experimental field is leached Chernozem, having a medium-loamy granulometric composition. The humus horizon depth is 40–45 cm, the humus content in the topsoil is 8.6%, the soil medium reaction is subacidic 5.8 pH (KCl). The soil consists of easily hydrolysable nitrogen (147 mg/kg), labile phosphorus (153 mg/kg), exchangeable potassium (170 mg/kg). The sum of active temperatures is 2200–2300 degrees. The average annual frost-free period is 120 days. The growing season from May to September precipitation is 225–275 mm with the average annual rainfall being 523 mm.

Herbicides are chosen according to the type of weed infestation. When annual grass weeds are predominant, maize is treated with soil herbicides: Frontier Optima, EC (0.8–1.2 l/ ha); Blokpost, EC (0.8–1.2 l/ha); Etalon, EC (0.8–1.2 l/ha). These herbicides are sprayed on the soil before sowing or immediately after sowing before the maize emergence. At mixed weed infestation Merlin, EC herbicide (0.16 kg/ha) can be used. It is applied immediately after sowing without sub-surface treatment.

Vegetation conditions in 2016 were characterized by hot and dry weather. The weather in April was warm with an average daily temperature of 9.1 ℃, that is 4.4 ℃ more than normal (Figure 1). The amount of rainfall was 44 mm, that is 12 mm more than normal. The average daily air temperature in May was 14.3 ℃ exceeding the norm by 1.3 ℃. Precipitation in may was two times less than normal (26 mm). In June, the air temperature (17.8 ℃) was above the norm by 0.4 ℃. The amount of precipitation was 56 mm, being within the climatic norm. The weather in July was warm and dry, the average daily temperature was higher than the norm by 1.6 ℃, and the amount of precipitation was only 32% of the norm. August was also hot and there was little rainfall. The average monthly air temperature was 23.0 ℃, that is 6.2 ℃ higher than the average annual data. The amount of precipitation was only 19 mm or 37% of the norm. In general, the sum of positive temperatures in 2016 for the period from May to September was 2713 ℃ or more by 326 ℃ than the long term average annual.

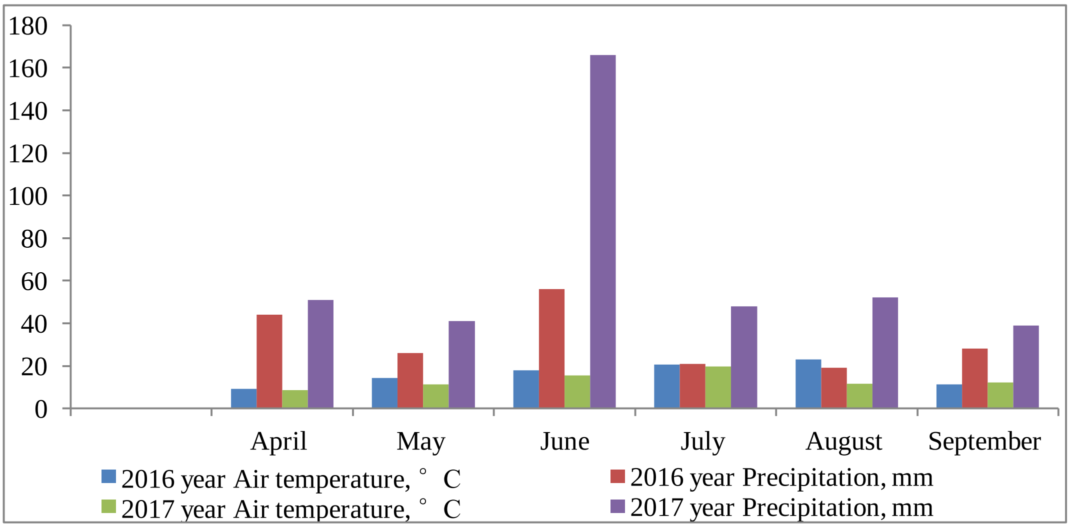

Figure 1. Meteorological conditions in the years of research (Scientific Training Center of Bashkir State Agrarian University).

Thus, May 2017 was cold, the average daily temperature was 11.4 ℃ being lower the norm (13.2 ℃) by 1.8 ℃. The air temperature on May 8 fell to minus. For the whole May there was heat shortage of 56 degrees. June was also a cool month. The air temperature was at the rate of. For the whole June, the heat shortage was 60 degrees. In June, precipitation was 166 mm or 252% of the norm. The weather in July and August was generally within the climatic norm. September was warmer than the long term annual average, temperature was 12.1 ℃ (the norm is 11.1 ℃). Thus, the weather conditions in the growing season of 2017, especially in May and June, were cool. The shortage of positive temperatures amounted to 116 degrees for these months. Though the temperature was a little higher the norm, the heat shortage remained during the subsequent period of maize growing.

The scheme of field experiments included the following maize hybrids: Nur, Mashuk 150, Ural 150, Atlant, Bilyar, Mashuk 170, Mashuk 175, Baikal, Mashuk 171, Katerina, Mashuk 185, Newton, Mashuk 220, Mashuk 250 and Mashuk 355. The area of plots is 140 m^2. There were three replications. The placement of hybrids is systematic. The preceding crop was spring wheat. Soil tillage was performed in autumn with PN-4-35 plowing to a depth of 26–28 cm. In spring there was harrowing (with 3B3TS-1.0) and pre-sowing cultivation. Maize was sown on May 10 with a seeding rate of 80,000 seeds per 1 ha using a UPS-8 planter with of 70 cm spacing.

During the growing season, the height and weight of plants were determined. Yield was performed by the continuous harvest method and weighing the mass of plants and grain after maize ear threshing. To conduct laboratory analysis grain samples were chosen. The area of experimental plots is 100 m^2. Grain moisture was determined with Wile-55 electronic moisture meter and the drying method in the drying chamber. The grain protein content was tested with Infralum FT-10 infra-red analyze (Russia production).

3. Results

In 2016 all the hybrids germinated simultaneously on the 11th day after sowing. The relatively high temperature in this year accelerated the maize growth. Ears of Nur, Mashuk 150 MV, Ural 150, Atlanta, Bilyar, Mashuk 170 MV, Mashuk 171 and Katerina SV hybrids emerged on July 4–6, bloomed on July 11–14, ripened on 23–24 August. Mashuk 175 MV, Baikal and Mashuk 185 MV hybrid grains achieved wax ripeness on August 25–26 while Newton, Mashuk 220 MV, Mashuk 250 SV and Mashuk 355 MV hybrid grains on September 3–13.

Initial growth processes in the studied hybrids were significantly different. On June 29, plant height ranged from 63.9 cm (Mashuk 250 SV) to 95 cm (Ural 150), the number of leaves varied from 6.4 pcs. (Mashuk 250 SV) to 8.8 pcs. (Ural 150), plant weight was from 210 g (Mashuk 250 SV) to 340 g (Ural 150).

In 2017, all the studied hybrids germinated on the 14th day after sowing. Further phenological stages of maize occurred much later that long-term annual average due to low heat supply. Maize ears got bloomed on 2–12 August. However, short-season and mid-early hybrids achieved wax ripeness on 10–12 October. Mid-season hybrids were in the phase of milk and milk-wax ripeness by the end of the growing season.

Grain moisture is an important indicator for harvest maize hybrids. In dry and hot 2016 hybrid grain moisture by the time to record maize productivity varied from 21,7 to 41.1%. Grain moisture of short-season hybrids was lower (21.7–30.3%) than of mid-early varieties (27.2–35.8%) and mid-season ones (32.5–41.1%). In 2017 grain moisture by the time to record maize productivity (October 14) was higher than in 2016. Depending on the hybrid it was 31.0–43.5%. At the same time, grain moisture of short-season hybrids was lower (31.0–34.1%) than that of mid-early varieties (36.1–36.8%) and mid-season ones (38.5–43.5%).

The above-ground mass of maize hybrids varied from 257 g (Mashuk 150 MV) to 354 g (Mashuk 355 MV) in 2016, from 169 g (Mashuk 150 MV) to 238 g (Mashuk 355 MV) in 2017. Both in 2016 and 2017 short-season hybrids formed the lower above-ground mass mid-season varieties (Table 1).

In 2016, there was high yield of the above-ground mass and grain (Table 1). Nur, Ural 150, Baikal, Mashuk 171 (5.28–6.71 t/ha) short-season hybrids, Mashuk 185 MV (7.18 t/ha) mid-early variety and Mashuk 355 MV (6.88 t/ha) maize had the highest grain productivity. The largest amount of corn grain was formed in hybrids Mashuk 185 MV (7.18 t/ha), Mashuk 355 MV (6.88 t / ha) and Mashuk 171 (6.71 t/ha), and the smallest in the Bilyar hybrid (3.89 t/ha). The yield of green mass was greater in the hybrid Mashuk 355 MV (31.0 t/ha) and Mashuk 250 SV (30.0 t/ha).

In 2017, in conditions of insufficient heat provision during the growing season, maize grain productivity was lower than in 2016. Mid-season hybrids suffered more. The highest grain productivity was performed by Mashuk 171, Nur, Uralsky 150, Baikal short-season hybrids (3.81–4.08 t/ha). Grain productivity of mid-early varieties was almost the same and did not differ significantly from the yield of short-season hybrids. Grain productivity of mid-season hybrids was lower than the yield of short-season varieties and ranged from 3.43–3.80 t/ha.

For two years contrasting in weather conditions, among short-season hybrids Mashuk 175 MW, Nur, Uralsky 150, Baikal and Mashuk 171 performed the highest grain productivity (3.79–4.66 t/ha). Grain productivity of mid-early varieties was almost the same and did not differ significantly from the yield of short-season hybrids. Grain yield of mid-season hybrids ranged from 4.82–5.16 t/ha.

Table 1. Above-ground mass (natural moisture) and grain productivity (at 14% moisture) of maize hybrids (Scientific Training Center of Bashkir State Agrarian University).

Hybrids	Productivity, t/ha					
	2016		2017		Average for 2016–2017	
	Above-ground mass	Grain	Above-ground mass	Grain	above-ground mass	grain
Nur	17.7	5.40	18.7	3.81	18.2	4.61
Mashuk 150 MV	16.0	4.83	16.9	3.77	16.5	4.30
Uralsky 150	20.2	5.28	19.8	3.84	20.0	4.56
Atlant	22.5	4.63	17.8	3.57	20.2	4.10
Bilyar	18.9	3.89	18.7	3.68	18.8	3.79
Mashuk 170 MV	18.4	4.27	18.9	3.76	18.7	4.02
Mashuk 175 MV	23.0	4.89	20.8	3.84	21.9	4.37
Baikal	19.7	5.39	20.3	3.93	20.0	4.66
Mashuk 171	28.0	6.71	21.7	4.08	24.9	5.40
Katerina SV	23.5	6.04	21.5	3.90	22.5	4.97
Mashuk 185 MV	29.1	7.18	22.1	3.91	25.6	5.55
Newton	24.8	6.59	22.8	3.80	23.8	5.20
Mashuk 220 MV	24.3	5.88	22.4	3.76	23.4	4.82
Mashuk 250 SV	30.0	5.90	23.1	3.71	26.6	4.81
Mashuk 355 MV	31.0	6.88	23.8	3.43	27.4	5.16
NSP 05		0.21		0.19		

Along with the yield, the value of maize hybrids cultivated for fodder purposes is determined by the protein content of the grain. On the average for two years the protein content in grain varied from 6.4% (Mashuk 355 MV) to 9.9% (Mashuk 150 MV). Of the studied corn hybrids, on average over the years of research, Mashuk 150 MV (9.9%), Mashuk 175 MV (9.7%) and Nur (8.6%) had the highest protein content in grain, and Mashuk 355 MV (6.4%) had the smallest. In corn grain hybrids, the starch was highest for Uralsky 150 (63.2%), Nur (61.7%) and Baikal (60.8%), and the smallest for Mashuk 355 MV (45.7%). (Table 2). The starch content also varied significantly from 45.7% (Mashuk 355 MV) to 63.2% (Uralsky 150).

Table 2. Protein and starch content of maize grain.

Hybrid	2016 year		2017 year		Average for 2016–2017	
	Protein, %	Starch, %	Protein, %	Starch, %	Protein, %	Starch, %
Nur	8.7	61.4	8.5	61.9	8.6	61.7
Mashuk 150 MV	9.8	57.3	10	58.2	9.9	57.8
Uralsky 150	7.7	62.8	7.9	63.5	7.8	63.2
Atlant	7.8	59.3	8.4	59.9	8.1	59.6
Bilyar	8.3	55.2	8.6	55.9	8.5	55.6
Mashuk 170 MV	8.4	57.3	7.8	58.3	8.1	57.8
Mashuk 175 MV	9.6	58.4	9.8	58.6	9.7	58.5
Baikal	7.6	60.7	7.2	60.9	7.4	60.8
Mashuk 171	8.6	60.1	7.9	60.5	8.2	60.3
Katerina SV	8.5	60.3	8.3	59.3	8.4	59.8
Mashuk 185 MV	7.2	58.2	7.6	59.3	7.4	58.9
Newton	7.3	53.4	8.2	53.9	7.8	53.7
Mashuk 220 MV	6.8	53.6	7.1	53.4	6.9	53.5
Mashuk 250 SV	7.1	50.3	6.9	50.1	7.0	50.2
Mashuk 355 MV	6.3	45.8	6.5	45.6	6.4	45.7
NSP 05	0.2	1.5	0.2	1.6	0.2	1.6

Production tests on farms, conducted on different natural areas of the Republic, proved high productivity of maize hybrids. In the LLC farm enterprise named after Kalinin being located in the Sterlitamak district, there were the following results. Grain productivity of Nur was 7.18 t/ha, Uralsky 150—7.26 t/ha, Bilyar—7.14 t/ha and Mashuk170 MV—7.64 t/ha. Maize grain yield in the agricultural production cooperative 'Urozhai' in the Aurgazy district of Bashkortostan was as follows: Nur: 8.5 t/ha (2017) and 5.62 t/ha (2018), Uralsky 150: 7.8 t/ha (2017) and 6.35 t/ha (2018), Baikal: 8.3 t/ha (2017) and 5.28 t/ha (2018), Bilyar: 7.6 t/ha (2017) and 5.81 t/ha (2018), Mashuk 170 MV: 7.46 t/ha (2017) and 5.34 t/ha (2018), Mashuk 175 MV: 9.2 t/ha (2017) and 4.29 t/ha (2018).

4. Discussions

The studied hybrids differed sharply in terms of the wax ripeness time and grain moisture, 37 above-ground mass and grain yield. Pettigrew concluded that different hybrids react differently regarding grain yield due to their genetic makeup and potential expressed in terms of difference in ears plant-1, number of grains cob-1 and 1000 grains weight [20].

Our results show that agrophysical properties of the soil did not depend on the break crop. Mustard turned to be the most effective break crop. Maize productivity on it was 8.1 t/ha. The best treater was 'Rubin' + PLN-4-35. It resulted in the highest yields for all variants which is consistent with [21–24].

The early-maturing hybrids Nur, Ural 150, Mashuk 150 MV and Mashuk 170 MV are found to be most suitable to cultivate maize for grain [6,7,25,26]. *Fusarium spp* and middle-early maize hybrids, being harvested early, are good forecrops for winter grain crops. Other studies confirm that their high cost effectiveness is manifested in fast water-yielding capacity and ability to provide dry grain that doesn't require drying after the harvest [27]. Maize for grain should be sown when the soil layer of 0–10 cm warms up to +8–10 °C.

5. Conclusion

Thus, different weather conditions in the studied years made it possible to evaluate and identify highly productive maize hybrids for the conditions of the Republic of Bashkortostan. In terms of ripening, yield and protein content in grain short-season hybrids (FAO 150–199) Nur, Uralsky 150, Mashuk 150 MV, Mashuk 170 MV are the most suitable for the conditions of the southern forest-steppe of the Republic. To get high-quality as well as high-energy silage, it is advisable to grow short-season hybrids Mashuk 171, Mashuk 175 MV, Mashuk 185 MV and Katerina SV. From mid-early hybrids Newton, Mashuk 220 MV and Mashuk 250 SV are recommended for silage production.

Conflict of interest

All authors declare no conflicts of interest in this paper.

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