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Research Article

The Influence of Different Seeding Application Rates and Sowing Time on Maize Hybrids' Productivity in the Conditions of the Republic of Bashkortostan's Southern Forest-Steppe Zone

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Maize takes the leading place in yield and is one of the most common crops in the world. Selection of the optimal seeding application rate and time is among the central issues in maize cultivation technology and is highly relevant. The research made in 2018–2020 aimed at improving the maize technology block for grain (seeding application rate and sowing time, southern forest-steppe, the Republic of Bashkortostan). For this purpose, a field experiment was launched in a fourfold replication. The experimental design included hybrids: Nur, Mashuk 171, Baikal and Mashuk 220 with a planting density of 60 (control), 70, 80, and 90 thousand pcs/ha. The experiment revealed a high correlation dependence of the yield of green mass and grain on the sowing time ($r = 0.876–0.915$ and $r = 0.951–0.963$). In the conditions of the Republic of Bashkortostan's southern forest-steppe, Baikal and Mashuk 171 hybrids are recommended to be used for animals and poultry diets and the planning of maize cultivation technological schemes at early sowing time (May 10) and a seeding application rate of 80 thousand pcs/ha. The results of the research apply to the formation of agricultural feeding diets.

1. Introduction

The low nutritional value of feed is one of the major problems in world agriculture. For solving this problem, it is necessary to develop new elements in traditional crop cultivation technologies while paying particular attention to fodder-grain crops [1, 2].

In the Republic of Bashkortostan, maize is considered a forage crop primarily. It is used for silage, corn age, and feed grain making and additional green feeding for animals [3].

Maize has a very high digestibility of 87–90%. Maize grain hull is hard and relatively rich in fiber. Its digestibility is entirely satisfactory due to the content of a small amount of starch and germ particles. Both maize grain, its stems, leaves, and other parts have a high digestibility. The share of grains makes 31–42% of the yield; the share of maize cobs without grains is about 10–11% [2].

In the Republic of Bashkortostan, maize is considered a forage crop primarily. It is used for silage, corn age, and feed grain making and additional green feeding for animals [3, 4].

As evidenced in practice, the most high-quality and nutritious feed is obtained when making forage from maize grain or tops containing grains of milky, milky-wax, and wax ripeness stages [3].

The Republic of Bashkortostan's natural conditions are characterized by a limited heat resource and a short growing season. Thus, for obtaining maize cobs with grains of milky-wax and wax ripeness, sowing should be carried out at earlier dates. Maize hybrids, which are resistant to cold, can be sown at a soil temperature of 5 – 7°C. The calendar period of maize sowing in the Republic of Bashkortostan is usually from May 1 to May 16. However, each year, the current and expected weather conditions should be taken into consideration.

Moreover, maize hybrids (early and midripening varieties, i.e., flint maize) are more resistant to cold, which should also be taken into account. Areas of these maize hybrids sown in the early dates are characterized by lower thinning. By the time of harvesting, they usually have maize cobs of milky-wax and wax ripeness. The occurrence of frost when the temperature is −3°C or lower in the pre-Ural and trans-Ural steppes in the 1st decade of June is 3–17%, thus 1 or 2 years of 10. In the southern forest-steppe, the frost occurrence makes 9–11%, i.e., once in 10 years. The long-term average annual date of the last spring frosts with an intensity of −3°C and below on the soil surface in the pre-Ural and trans-Ural steppes is May 16–24, and in the southern forest-steppe, it is May 12–22 [5].

When determining the sowing period, the last spring frosts should be taken into account. Maize seedlings at the soil surface level are severely damaged or die during frosts when the temperature is −3°C or lower. Only the leaves are usually damaged with less intense frosts, and new leaves grow back within a week. However, this leads to a delay in plants growth and development and the formation of a low grain yield [6, 7].

In the studies of Mingalev [8] during 2005–2017, experiments were conducted to assess the effect of the sowing period, crop care techniques, and standing density on the yield and nutritional value of green mass and maize hybrids grain (conditions of the middle Urals). The experiment showed that the density of sowing increased to 100 thousand/ha, which led to an increase in the yield of green mass and dry matter of hybrids. However, there was also a decrease in the proportion of cobs and forage depreciation as a result. In the middle Urals conditions, for obtaining a green mass with a high dry matter content, the best sowing time for quickly ripening maize hybrids is May 20–30. May 1–10 is the best sowing period for obtaining a high grain yield [8].

Research conducted in Serbia by Mandić et al. [9] proves the effectiveness of earlier crops, taking into account climatic conditions. A field experiment conducted to study the effect of two sowing dates (April 8, the first sowing date, and April 21st, the second sowing date) and four nitrogen norms (0, 60, 120, and 180 kg/ha) on plant yield showed that the highest number of grains in the ear, starch, and oil content, starch and oil yield, and lower precipitation efficiency (RUE) and protein content were obtained during the early sowing period [9].

The date of planting and the choice of variety are the main factors in determining the potential yield capacity of any crop in any region. To explore this gap, Baum et al. [10] performed a regional scale analysis (11 planting dates × 8 cultivars × 281 fields × 36 weather years × 6 climate scenarios) using the APSIM model and pSIMS software for Iowa, the leading US maize (*Zea mays L.*) producing state. Results indicated that the mean optPD corresponds to the US Department of Agriculture, National Agriculture Statistics Service (USDA-NASS) 18.4% planting progress (April 28) in Iowa. A simple economic analysis showed a potential loss of income of up to $340 million per year due to maize planting outside the optimal window [10].

The sowing period and the application of nitrogen (N) fertilizers change maize plants' morphophysiological characteristics (*Zea mays L.*), affecting the yield. Studies conducted in Brazil by Coelho et al. [11] to analyze the effect of the sowing date and the nitrogen rate on the growth characteristics of maize hybrids with contrasting cycles and their subsequent relationship with grain yield in the state of Santa Catarina in southern Brazil have shown that the use of increasing nitrogen rates is an adequate management strategy to increase the yield of maize grain sown in early spring [11].

Scientists Abbas et al. [12] considered a slightly different approach in their research. Maize can be sown in the spring and fall seasons in Pakistan under the maize-maize cropping system. For optimizing the planting time of hybrids, two-year experiments were conducted in 2016 and 2017. In the spring, three hybrids were sown: on January 15, February 5, February 25, March 15, and April 5. In the fall, three hybrids were sown: on June 15, July 5, July 25, August 15, and September 05. Thus, the spring season seemed more productive than the fall season under maize-maize cropping system [12].

Heat stress due to rising temperature reduces the number of grains and spring maize yield in the North China Plain (NCP). Previous studies have recommended moving the spring maize sowing date to the end of May in the UPC to mitigate heat stress. However, another field experience has shown that early sowing can provide a high grain yield. For addressing the imbalance in previous studies, Gao et al. [13] conducted a two-year experiment to study the yield's dependence on seeding dates. The experiment lasted from April 4 to June 13, with a 14-day interval without drought stress. The experiment showed that high grain yields were obtained in the first sowing periods (early and mid-April) in both years [13].

Grabovskii [14] studied the influence of sowing dates on the plants' growth and development, the duration of interstage periods, and maize productivity when sown with sugar sorghum. Over the years of his research, he found that when maize and sugar sorghum are sown at the same time, the field germination of maize seeds is 78.3%, which is 1.5, 2.9, and 5.2% less in comparison with the following sowing periods. Maize and sugar sorghum companion planting increased the maize growth season's duration by 1-2 days from the first sowing period to the fourth. The sugar sorghum growth season remained almost unchanged (127-128 days). The yield of the green and dry mass of the variants of the first four periods tended to decrease. However, there was no significant difference between the experimental variants [14].

Precision single maize seeding, reducing the cost of seedling thinning, is becoming one of the most popular technical innovations of maize production in China. Researchers Zhongzhi et al. [15] found that it is necessary to sow several seeds in one hole to get 100% germination of seedlings. Sowing one seed in one hole reduced the maize yield by 0.06–16.78% [15].

Kadyrov and Kharitonov [16] studied the optimal seeding application rates and the maize hybrids planting density (different ripeness groups, forest-steppe of the Central Chernozem region). Their research noted the seeding application rate's influence on the yield and grain quality of various maize hybrids. The maximum grain yield was observed in hybrids Rodnik 179 SV (quickly ripening variety) and MAS 12R (quickly ripening variety) and amounted to 6.39 and 6.73 t/ha. The maximum grain yield was also observed in the hybrid AMELIOR (midripening variety), amounting to 6.81 t/ha when sowing 73 thousand pieces of seeds per ha. When the seeding application rate is less than 67 thousand units/ha or more than 73 thousand units/ha, there is a decrease in the maize yield [16].

Turkish scientists Malasli et al. [17] studied different rates of maize seeding under zero tillage in the conditions of Erzurum. For this purpose, three silage varieties (DKC-5783, Prestige, and ADA-9510) suitable for the climatic conditions of Erzurum were selected. For sowing maize for silage, a precise double-disk vacuum planter was used. Based on three different distances between seeds (10, 15, and 20 cm), the soil's physical properties, plant germination, yield and yield parameters, and the sowing machine's productivity were studied. When the row spacing between the seeds was 20 cm (DKC-5783 and ADA-9510), the results were the best [17].

Much attention is paid to the study of the maize seeding rate in India. According to Kumar et al. [18], the combined use of the seeding rate of 60 kg/ha and 125% RDF allowed for a significant maximum yield of green (61.7 t/ha) and dry feed (14.1 t/ha). A field study to assess the impact of different planting densities and fertility levels on the yield and quality of forage maize was conducted during the 2014 and 2015 Kharif season at ICAR-NDRI, Karnal (*Zea mays L.*). The experiment was conducted on a divided plot where the main plot with a planting density of 60, 75, and 90 kg of seeds/ha was cultivated three times. The plot of nutrient levels, i.e. 0, 50, 75, 100, 125, and 150, was cultivated six times. The recommended fertilizer dose (RDF) is 120 kg N/ha and 60 kg P2O5/ha [18].

Studies conducted in the United States by scientists Licht et al. [19] showed that three plot-years showed a negative linear response of the seeding rate, making it impossible to determine the optimal seeding rate above the cultivation with the lowest seeding rate. This study aimed at developing procedures for optimizing maize seeding rates and increasing yields using soil and topographical parameters. Experimental cultivations included five seeding rates (61 750; 74 100; 86 450; 98 800; and 111,150 ha-1 seeds) in a randomized complete block in three fields in central Iowa from 2012 to 2014 (nine plot-years) [19].

In his research, Anders et al. [20] point to maize plants' changes occurring when the seeding rate changes in Poland. The field experiment was conducted in 2011–2013. When the distance of 0.75 m between rows is constant, the seeding rate (from 6.5 to 11.9 seeds per m2 for "Kosmo" and from 8 to 12 seeds per m2 for "Kikso") significantly ($\alpha = 0.05$) affects the estimated parameters. The higher plant density resulted in the weight loss of the plants and ears. Thus, the stem diameter became smaller. The seeding rate increase led to a decrease in the stem diameter measured at 50, 100, and 150 cm above the ground (by about 11–23% in the Cosmo variety and by about 3–13% in the Kikso variety). The stem length increased (from 10% to 13% in the Kosmo variety and about 8% in Kixxo variety). Plants grown with a lower seeding rate were bigger and heavier [20].

According to the studies of Eskov et al. [21], on average for 2017–2019, when a seeding rate is 50 thousand seeds per 1 ha by the panicle heading phase, the leaf surface of the midripening hybrid Raduga was 35.20 thousand m2/ha, which is higher compared to the quickly ripening hybrid Mashuk 185 MV (31.82 thousand m2/ha) and the ultra-quickly ripening hybrid RNIISK-1 (26.31 thousand m2/ha). With an increase in the seeding rate of more than 50 thousand seeds per 1 ha, the leaf surface of all hybrids increased. The minimum leaf surface is marked at the seeding rate of 40 thousand seeds per 1 ha. In the ultraquickly ripening maize hybrid RNIISK-1, the accumulation of green and dry biomass was similar to the leaf surface's formation and depended on the seeding rate. In the quickly ripening Mashuk 185 MV hybrid and the midripening Raduga hybrid, green and dry biomass accumulation did not depend on the seeding rate [21].

Accordingly, the seeding rate and the density of standing maize plants cultivated according to silage technology differ significantly from grain production technology. The optimal plant density for quickly ripening hybrids is 65–71 thousand units/ha in grain production. Moreover, both the optimal number of plants and their uniform spacing per area unit are essential. The calculation of the seeding rate and the number of plants per linear meter is made, taking into account the seed material's economic suitability, the field germination of seeds in natural zones, and the plants dyewood when taking care of crops. Field germination of maize seeds in the Republic of Bashkortostan's production conditions is usually 80–85%. Therefore, when using the single-seed sowing method with a row spacing of 70 cm, it is necessary to sow 5–6 seeds of quickly ripening and midripening hybrids per running meter. The seeding rate is 19–26 kg/ha when considering the germination rate and the weight of 1000 grains [22].

A review of the conducted studies shows that seeding rates and sowing date highly depend on the experimental site's soil and climatic conditions. In this regard, the research of 2018–2020 aimed at improving the technology block (seeding rate, sowing time) of maize for grain in the conditions of the southern forest-steppe of the Republic of Bashkortostan.

Thus, the tasks of the research included determining the yield of maize hybrids at different sowing time, determining the yield of maize hybrids at different seeding rates, determining the quality of maize hybrids at different sowing time, and determining the quality of maize hybrids at different seeding rates. The research on the maize hybrids studied in the conditions of the Republic of Bashkortostan's southern forest-steppe is conducted for the first time.

2. Materials and Methods

Field experiments were conducted in 2018–2020 at the experimental field of the Bashkir State Agrarian University (Department of Crop Production, Plant Breeding and Biotechnology). The soil was heavy loam leached chernozem. The soil contained 131–153 mg/kg of easily hydrolyzable nitrogen, 161–165 mg/kg of mobile phosphorus, and 184–189 mg/kg of exchangeable potassium. Spring wheat was the preceding crop in the experiment. The agricultural technique used in the experiments was generally accepted for the zone. The humus horizon thickness was 55–67 cm with a humus content of 9.4–9.8%. The volume mass of the soil of the arable layer was 1.01–1.09 g/cm^3. The reaction of the soil medium was slightly acidic $pH_{(csl)}$6,15–6,31.

Experiment 1. Study of the influence of different seeding rates (thousand pcs/ha). The following variants were studied:

$$60\,(\text{control});\ 2.70, 3.80, 4.90. \tag{1}$$

The following hybrids were used in the research: Nur, Mashuk 171, Baikal and Mashuk 220.

Experiment 2. Study of the effect of different sowing periods on the productivity of maize hybrids. The following variants were studied:

(1) May 10 (early sowing period, control); 2. May 20 (medium); 3. May 30 (late)

The following hybrids were used in the research: Nur, Mashuk 171, Baikal and Mashuk 220.

The field experiment was carried out in a systematic way; the replication was fourfold. The area of the working plots was 150 m^2. The registration plot area was 50 m^2. Records, observations, and analyses were carried out following generally accepted methods.

The technology of corn cultivation included plowing with a seam turnover of 28 cm and leveling the soil surface in 1 track diagonally in autumn, spring harrowing and application of mineral fertilizers NPK (13 : 19 : 19) = 400 kg (physical weight), treatment with a continuous herbicide actions Hurricane Forte HP = 2 l/ha 1-2 weeks before sowing, presowing cultivation and sowing with the introduction of mineral fertilizers (ammonium nitrate, 200 kg physical weight), spraying with Elumis herbicide = 1.5 l/ha in phase 3–5 leaves, treatment with insecticide Ampligo = 0.3 l/ha in the phase of 8–10 leaves, and harvesting for silage in the phase of milky-wax ripeness.

Preliminary accounting of the yield of green mass of corn was carried out in the phase of milky-wax ripeness. In 4 repetitions, 2 rows of 14.8 m in length were mowed at a cut height of 30–35 cm. The results were compared with the harvesting of green mass with a combine, which is presented in the article as a final one. The corn grain was harvested by hand. Taking into account the area indicated earlier in each of the 4 replications, the ears were broken out and threshed on a thresher. During threshing, the moisture content of the grain was determined with a moisture meter. The grain yield was recalculated to 14% moisture. The quality of corn grain was determined according to GOST Р 53903-2010 [23].

The territory of the experimental field (according to agroclimatic zoning) belongs to a relatively warm and medium-humid area. Climatic conditions are continental, with dry air. There are sharp climatic vagaries and a sharp change in air temperature.

The territory of the southern forest-steppe is insufficiently humid with annual precipitation of 473–574 mm. The precipitation distribution is highly uneven. The sum of the effective temperatures is $2101-2305^{\circ}$C. The hydrothermal coefficient is 1.06–1.23. The arrival of PhAR (active photosynthetic radiation) is from 1920 to 2884 kcal/ha.

Meteorological conditions during the study periods of 2018–2020 as a whole (especially in May and June) were cool and warm with a shortfall of positive temperatures for these two months at the level of $115-155^{\circ}$C.

3. Results

The experiments revealed that the studied maize hybrids' plants had a height of 174.0–281.0 cm before harvesting. The hybrids Mashuk 220 (281 cm) and Baikal (260 cm) had the highest indicators on the first sowing date on May 10. The lowest height indicators were obtained when cultivating the Nur hybrid (175 cm) on a late sowing date on May 30. When studying the seeding rate experiment, the hybrids Mashuk 220 SV with a height of 275 cm and Mashuk 171 with 265 cm (60 thousand plants per ha) showed the best plant height indicators. The lowest height in this experiment had the hybrid Nur-170 cm at 90 thousand plants per ha. A high correlation between plant height and green mass yield was revealed ($r = 0.812–0.823$).

The study of the yield of green mass of maize (milky-wax grain ripeness phase) showed that the green maize mass of the hybrids studied in the experiment depends on the sowing time and can reach the level of 21.04–39.77 t/ha (Table 1).

The analysis of the obtained data on the yield of green mass shows the high crop efficiency of maize sown on May 10. In this variant of the experiment, the yield was 31.2–31.6% higher than the variant of the sowing time on May 20 and 59.0–70.6% higher compared to the variant of May 30. The highest yield in the experiment was obtained using the hybrids Baikal (39.77 t/ha) and Mashuk 220 (39.56 t/ha). The experiment revealed a high correlation between the yield of green mass and grain on the sowing time ($r = 0.876–0.915$).

The maize grain yield highly depends on the time of sowing ($r = 0.951–0.970$). The maize sowing carried out on

Table 1: The yield of maize hybrids at different sowing time.

Hybrids	Green mass t (ha)	Grain yield t (ha) (at 14% humidity)	Grain moisture during harvesting (%)
Sowing on May 10 (control)			
Nur	35.91	6.38	24
Mashuk 171	38.81	6.47	27
Baikal	39.77	6.48	27
Mashuk 220	39.56	4.72	41
Sowing on May 20			
Nur	27.28	4.74	26
Mashuk 171	29.12	5.39	29
Baikal	29.45	5.30	28
Mashuk 220	30.30	3.53	44
Sowing on May 30			
Nur	21.04	4.12	27
Mashuk 171	25.00	4.53	30
Baikal	24.97	4.51	30
Mashuk 220	22.51	3.14	47
NSR 05	0.03	0.01	0.97

May 10 was the most effective. The yield was 20.4–33.7% higher than the yield of sowing on May 20 and 43.0–50.3% higher compared to the yield of maize grain sown on May 30. The highest grain yield in the experiment was formed by the hybrids Baikal (6.48 t/ha) and Mashuk 171 (6.47 t/ha).

The sowing time in the Republic of Bashkortostan conditions is the main factor determining the productivity of maize sowing since the sum of positive temperatures in the Republic of Bashkortostan conditions is in the range of 1700–2200 degrees. In late sowing, the lack of heat is a critical factor. This experiment's sowing time affected the protein and starch content in the grain of the studied maize hybrids (Table 2).

The data analysis in Table 2 shows the protein and starch content's tendency to reduce when sowing on May 20th and 30th, compared with the control variant. When sowing on May 20, the decrease in protein content was 0.6–0.8% (8.4–10.2% in the control variant) or 6.2–10.5%. The decrease in starch content was 1.0–1.9% (59.2–68.1% in the control variant) or 1.4–3.3%. When sowing on May 30, the protein content decrease was 2.3–2.5% or 32.4–37.7% and the decrease in the starch content was 3.0–3.9% or 4.6–7.0%. The protein and starch content in the grain was the highest at the early sowing time (May 10) in the hybrid Nur, 10.2% and 66.3%, and Baikal, 10.1% and 68.1%, respectively.

According to the second experiment results, the maize aboveground mass yield is dependent on the seeding rate (high, $r = 0.815–0.861$). When the seeding rate increases to 70–80 thousand pcs/ha, there is an increase in the aboveground mass and grain yield. The increase in the seeding rate to 90 thousand pcs/ha had a negative impact on the maize yield (Table 3).

The data analysis in Table 3 on the yield of the green mass shows an increase in the yield of crops with an increase in the seeding rate compared to the control variant. With the increase in the seeding rate of maize seeds to 70 thousand pcs/ha, there was an increase in the green mass yield by 3.15–4.71 t/ha (by 24.59–25.10 t/ha in the control variant) or by 12.54–17.85%. With the increase in the seeding rate of maize seeds to 80 thousand pcs/ha, there was an increase in the green mass yield by 11.32–14.46 t/ha or by 44.51–57.6%. With an increase of the seeding rate to 90 thousand pcs/ha, the green mass yield increased by 2.01–3.62 t/ha or 8.00–13.54%. The highest yield in the experiment was obtained when the Baikal hybrid was used (39.77 t/ha with the seeding rate of 80 thousand pcs/ha).

Table 2: The quality of maize hybrids sown at different sowing time.

Hybrids	Protein (%)	Starch (%)
Sowing on May 10 (control)		
Nur	10.2	66.3
Mashuk 171	9.9	61.1
Baikal	10.1	68.1
Mashuk 220	8.4	59.2
Sowing on May 20		
Nur	9.5	65.3
Mashuk 171	9.6	59.1
Baikal	9.5	67.1
Mashuk 220	7.6	57.3
Sowing on May 30		
Nur	7.7	61.8
Mashuk 171	7.2	58.5
Baikal	7.3	65.1
Mashuk 220	6.1	55.3
NSR 05	0.11	0.19

The maize grain yield analysis shows an increase in the crop yield with an increase in the seeding rate to 70–80 thousand pcs/ha (to 60 thousand pcs/ha in the control variant). With the increase in the norm to 90 thousand pcs/ha, there was a significant increase in grain yield in the hybrids Nur (5.21 t/ha) and Baikal (5.22 t/ha). As for the experiment in general, an increase in the seeding rate of maize seeds to 70 thousand pcs/ha contributed to an increase in grain yield by 0.24–1.35 t/ha (by 3.43–4.96 t/ha in the

Table 3: The yield of green mass and grain of maize hybrids depending on the seeding rate.

Seeding rate, thousand pcs (ha)	Green mass t (ha)	Grain yield t (ha) (at 14% humidity)	Grain moisture during harvesting (%)
Nur			
60 (control)	24.59	26	4.22
70	28.98	26	5.57
80	35.91	26	6.38
90	27.92	25	5.21
Mashuk 171			
60 (control)	26.85	29	4.93
70	31.56	29	5.17
80	38.81	28	6.47
90	30.47	29	4.80
Baikal			
60 (control)	26.95	28	4.96
70	30.89	28	5.78
80	39.77	28	6.48
90	29.40	27	5.22
Mashuk 220			
60 (control)	25.10	45	3.43
70	28.25	45	4.23
80	39.56	44	4.72
90	27.11	45	3.51
NSR 05	0.3	1	0.14

control variant) or by 4.86–31.99%. The increase in the seeding rate of maize seeds to 80 thousand pcs/ha resulted in an increase in grain yield by 1.29–2.16 t/ha or by 30.64–51.18%. With the increase in the seeding rate of maize seeds to 90 thousand pcs/ha, there was an increase in the grain yield by −0.13–0.99 t/ha or 2.63–23.4%. The highest grain yield was obtained when the Baikal hybrid was used (6.48 t/ha with the seeding rate of 80 thousand pcs/ha).

The research results revealed that the seeding rate impacted the maize hybrids' grain quality studied in the experiment (Table 4).

The data analysis in Table 4 shows a tendency of the protein content to increase with an increase in the seeding rate. An increase in the seeding rate of maize seeds to 70 thousand pcs/ha contributed to an increase in protein by 0.2–0.5% (by 7.9–9.3% in the control variant) or by 2.53–5.37%. When the seeding rate increased to 80 thousand pcs/ha, the protein also increased by 0.5–0.9% or 6.32–9.67%. With the increase in the seeding rate to 90 thousand pcs/ha, there was an increase in protein by 0–0.4% or 0–4.39%. The highest protein content of 10.2% (80 thousand pcs/ha) was obtained when the Nur hybrid was used.

The experiment showed an increase in the starch content with an increase in the density of plants. An increase in the seeding rate of maize seeds to 70 thousand pcs/ha contributed to an increase in the starch content by 0.9–1.7% (by 55.6–62.3% in the control variant) or by 1.50–3.05%. When the seeding rate increased to 80 thousand pcs/ha, the starch content also increased by 1.8–8.3% or 3.03–13.84%. With the increase in the seeding rate to 90 thousand pcs/ha, there was an increase in the starch content by 0.9–6.7% or 1.51–11.20%. When using the Baikal hybrid, the highest starch content was obtained with a seeding rate of 80 thousand pcs/ha (68.1%).

Table 4: The quality of maize hybrids depending on the seeding rate.

Seeding rate, thousand pcs (ha)	Protein (%)	Starch (%)
Nur		
60 (control)	9.3	62.3
70	9.8	63.8
80	10.2	66.3
90	9.7	65.1
Mashuk 171		
60 (control)	9.1	59.3
70	9.3	60.2
80	9.9	61.1
90	9.5	60.2
Baikal		
60 (control)	9.3	59.8
70	9.6	60.7
80	10.1	68.1
90	9.3	66.5
Mashuk 220		
60 (control)	7.9	55.6
70	8.1	57.3
80	8.4	59.2
90	8.0	57.1
NSR 05	0.08	0.09

4. Discussion

Maize takes the leading place in yield and is one of the most common crops in the world. Selection of the optimal seeding application rate and time is among the central issues in maize cultivation technology and is highly relevant. According to Miller et al. [24] (northern forest-steppe of the Tyumen Region), the differentiated method with a seeding application rate of 120 thousand seeds per hectare has many points in its favour. The yield was 35.4 t/ha [24]. These studies partially coincide with the results of the experiments of the Italian scientists Testa et al. [25]. This work proved that, in the conditions under which the experiments were conducted, a high planting density of up to 10.5 plants per m^2 can significantly increase yield, but only in combination with narrow row spacing. These conditions increase plant stress and alter plant morphology and development to the detriment of individual plant yields. However, a lower yield per plant is fully compensated by a higher plant population.

At the same time, Surin [26] notes in his studies that the maize green mass yield increases with an increase in the seeding application rate, which is consistent with the research results mentioned in this paper. The yield of green mass increased with the increase in the planting density. However, an increase in the seeding application rate above 100 thousand pcs/ha did not affect the yield [26]. Thus, many authors' studies prove a tendency of the green mass yield to increase with an increase in standing density. Depending on the soil and climatic conditions, the green mass yield can range from 80 to 120 thousand pcs/ha. However, when using maize for farm animals feeding, the most important is not the green mass yield, but its content.

According to the studies of Autlov et al. [27] (steppe zone of the Kabardino-Balkar Republic), the maximum grain yield was obtained using the hybrid Krasnodar 421 SV (midlate) sown on April 30 and May 10 [27]. This partially coincides with the results of this research since the soil and climatic conditions of the Kabardino-Balkar Republic are much milder compared to the conditions in the Republic of Bashkortostan [28]. Moreover, these research results completely coincide with the research results of a group of Chinese scientists. According to Meng et al. [29], a comprehensive review of the yield and efficiency of water and fertilizer use allows concluding that early sowing (on April 10) is good from the point of view of full utilization of fertilizers and water resources. A field experiment using a complete block design was conducted at the experimental agricultural and environmental water-saving station of the Chinese Agricultural University in the Shiyang River Basin. The cultivation was carried out on three sowing dates, namely, *S*1 : (2018-04-10), *S*2 (2018-04-20), *S*3 (2018-04-30), at two irrigation rates, i.e., 80% ETc (I80), 100% ETc (I100) (ETc was crop evapotranspiration), and four nitrogen application levels, i.e., *N*0, *N*120, *N*180, *N*240 [29].

5. Conclusions

The conducted studies show that when cultivating the maize hybrids presented in the experiment, it is possible to obtain 21.04–39.77 t/ha of the green maize mass and 3.43–6.48 t/ha of grain. The experiment revealed a high correlation dependence of the yield of green mass and grain on the sowing time ($r = 0.876$–0.915 and $r = 0.951$–0.963). In the conditions of the Republic of Bashkortostan's southern forest-steppe, Baikal and Mashuk 171 hybrids are recommended to be used at early sowing time (May 10) and a seeding application rate of 80 thousand pcs/ha.

The research results are applicable to form animals and poultry diets and technological schemes for maize cultivation.

Data Availability

All data will be available on request from the corresponding author.

Conflicts of Interest

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

References

[1] A. T. Omokanye, F. M. Kelleher, and A. McInnes, "Crop residues for mulch, feed yield and quality as influenced by low-input maize-based cropping systems and N fertilizer," *Agricultural Journal*, vol. 8, no. 5, pp. 222–231, 2013.

[2] J. Xu, H. Han, T. Ning, Z. Li, and R. Lal, "Long-term effects of tillage and straw management on soil organic carbon, crop yield, and yield stability in a wheat-maize system," *Field Crops Research*, vol. 233, pp. 33–40, 2019.

[3] I. S. Nasyrov, A. M. Mukhametshin, I. I. Surakov et al., *Maize Cultivation Technology for Grain Production in the Republic of Bashkortostan*, pp. 1–40, All-Russian Scientific Research Institute of Maize, Bashkir State Agrarian University, Ufa, Russia, 2016.

[4] N. K. Yuldasheva, S. D. Gusakova, D. K. Nurullaeva, N. T. Farmanova, R. P. Zakirova, and E. R. Kurbanova, "Neutral lipids of oats fruit (*Avena Sativa* L.)," *Drug Development and Registration*, vol. 9, no. 4, pp. 40–43, 2020.

[5] R. R. Ismagilov, B. G. Ahiyarov, R. K. Kadikov, and K. R. Ismagilov, *Plant Growing Products Production for a Specified Purpose*, Bashkir State Agrarian University, Ufa, Russia, 2016.

[6] V. S. Sotchenko and V. N. Bagrintsy, "Maize Cultivation Technologies," *Bulletin of agricultural production of Stavropolie*, vol. 52, pp. 79–84, 2015.

[7] E. R. Khasanov, I. I. Gabitov, S. G. Mudarisov et al., "Justification of parameters of seed treater with an eccentrically fixed drum influencing the motion character and seed treatment modes," *Bulgarian Journal of Agricultural Science*, vol. 25, no. 2, pp. 119–128, 2019.

[8] S. K. Mingalev, "Influence of standing density, sowing period and care methods on the productivity of maize hybrids in the conditions of the Middle Urals," *Agrarian Bulletin of the Urals*, vol. 5, no. 172, pp. 38–43, 2018.

[9] V. Mandić, Z. Bijelić, V. Krnjaja et al., "Sowing and fertilization strategies to improve maize productivity," *Maydica*, vol. 65, no. 12, pp. 1–9, 2020.

[10] M. E. Baum, M. A. Licht, I. Huber, and S. V. Archontoulis, "Impacts of climate change on the optimum planting date of different maize cultivars in the central US corn belt," *European Journal of Agronomy*, vol. 119, Article ID 126101, 2020.

[11] A. E. Coelho, L. Sangoi, A. A. B. Junior et al., "Growth patterns and yield of maize (*Zea mays*) hybrids as affected by nitrogen rate and sowing date in southern Brazil," *Crop and Pasture Science*, vol. 71, no. 12, pp. 976–986, 2021.

[12] G. Abbas, S. Ahmad, M. Hussain et al., "Sowing date and hybrid choice matters production of maize-maize system,"

International Journal of Plant Production, vol. 14, no. 4, pp. 583–595, 2020.

[13] Z. Gao, H.-Y. Feng, X.-G. Liang et al., “Adjusting the sowing date of spring maize did not mitigate against heat stress in the North China Plain,” *Agricultural and Forest Meteorology*, vol. 298–299, Article ID 108274, 2021.

[14] M. B. Grabovskii, “Justification of the maize sowing time in joint crops with sugar sorghum,” *Agrobiology*, vol. 1, no. 138, pp. 67–76, 2018.

[15] H. Zhongzhi, C. Hongbo, G. Hongyan, Y. Yan, and Y. Jinzhong, “Monte-Carlo simulation of yield effect under singular seeding strategy in maize based on Voronoi diagrams,” *Transactions of the Chinese Society of Agricultural Engineering*, vol. 31, no. 13, pp. 17–21, 2015.

[16] S. V. Kadyrov and M. I. Kharitonov, “Yield and quality of maize seeds at different seeding rates,” *Bulletin of the Voronezh State Agrarian University*, vol. 1, no. 48, pp. 12–16, 2016.

[17] M. Z. Malasli, A. Çeľik, and A. Celik, “The effects of different plant densities and silage corn varieties on silage yield and some yield parameters in no-till seeding,” *Turkish Journal of Agriculture and Forestry*, vol. 41, no. 6, pp. 490–499, 2017.

[18] R. Kumar, M. Singh, B. S. Meena et al., “Quality characteristics and nutrient yield of fodder maize (*Zea mays*) as influenced by seeding density and nutrient levels in Indo-Gangetic Plains,” *Indian Journal of Agricultural Sciences*, vol. 87, no. 9, pp. 1203–1208, 2017.

[19] M. A. Licht, A. W. Lenssen, and R. W. Elmore, “Corn (*Zea mays L.*) seeding rate optimization in Iowa, USA,” *Precision Agriculture*, vol. 18, no. 4, pp. 452–469, 2017.

[20] A. Anders, P. Markowski, S. Konopka, Z. Kaliniewicz, A. J. Lipinski, and D. J. Choszcz, “Effect of seeding rate on selected physical parameters and biomass yield of maize,” *Chilean Journal of Agricultural Research*, vol. 80, no. 2, pp. 171–180, 2020.

[21] I. D. Eskov, N. V. Nikolaichenko, N. I. Strizhkov, and I. K. Zhumagaliev, “Influence of the seeding rate of seeds on the productivity of various corn hybrids in the conditions of the Saratov Right Bank,” *The Agrarian Scientific Journal*, vol. 1, no. 1, pp. 8–13, 2021.

[22] V. S. Sotchenko, I. Kuznetsov, B. G. Akhiiarov, L. M. Akhiiarova, and B. N. Sotchenko, “Maize hybrids of the selection of the federal state budgetary scientific research institute of maize chosen for the conditions of the republic of bashkortostan,” *Maize and sorghum*, vol. 1, pp. 3–8, 2018.

[23] GOST P 53903-2010. Feed Corn. Specifications, Codex JSC, *National Standard of the Russian Federation*, GOST P 53903-2010. Feed Corn. Specifications,” Codex JSC, (in Russian), 2011.

[24] E. I. Miller, V. V. Rzaeva, and S. S. Miller, “Influence of basic tillage and seeding rate on the yield of green mass of maize in the northern forest-steppe of the Tyumen region,” in development of scientific, creative and innovative activities of young people,” in *Proceedings of the IX All-Russian Scientific and Practical Conference of Young Scientists*, pp. 233–236, Moscow, Russia, 2017.

[25] G. Testa, A. Reyneri, and M. Blandino, “Maize grain yield enhancement through high plant density cultivation with different inter-row and intra-row spacings,” *European Journal of Agronomy*, vol. 72, pp. 28–37, 2016.

[26] I. V. Surin, “Influence of the seeding rate on the yield and quality of the maize crop of the hybrid “Katerina SV” when growing on green mass with cobs of milk-wax ripeness,” *Youth and science*, vol. 1, pp. 7–9, 2012, (in Russian).

[27] Z. Z. Autlova, Iu.M. Shogenov, and A. M. Temirzhanov, ““The quality of cereals depending on the terms of maize hybrids sowing in the conditions of the Kabardino-Balkar Republic,” in actual problems of agronomy of modern Russia and ways of their solution,” in *Proceedings of the International Scientific and Practical Conference Dedicated to the 105th Anniversary of the Faculty of Agronomy, Agrochemistry and Ecology*, pp. 193–197, Voronezh, Russia, 2018.

[28] K. Kaimuldinova, “Toponymic evidence of change in the water regime of the lakes in Kazakhstan,” *World Applied Sciences Journal*, vol. 30, no. 2, pp. 161–166, 2014.

[29] X.-C. Meng, F.-C. Zhang, L.-J. Liu, J.-S. Lu, P.-R. He, and C. Xiao, “Effects of sowing date and water-nitrogen interaction on the growth and water and nitrogen utilization of spring maize under drip fertigation,” *Journal of Plant Nutrition and Fertilizers*, vol. 26, no. 10, pp. 1794–1804, 2020.