Realizing the genetic potential of corn hybrids in Central Non-black-soil region

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Abstract. In a field experiment in 2019, the growth, development and formation features of 34 corn hybrids yield were studied in Skopa Ltd., Sonkovsky district, Tver region (Russia). 4 groups of hybrids with different productivity, average green mass yield with ears and absolutely dry phytomass (t/ha) were revealed: 1 – 6 hybrids (17.6%) 79.48 and 18.55; 2 - 6 hybrids (17.6%) 58.97 and 11.1; 3 – 13 hybrids (38.2%) 41.1 and 9.4; 4 – 9 hybrids (26.1%) 31.2 and 7.3 t/ha. The most productive were the hybrids LG 30189 (LimaGrain, France) and Zeta 110 S (LABOULET, France), which has a green mass yield of 87.5 and 91.8 t/ha, of absolutely dry mass – 21.39 and 18.52 t/ha, the PAR efficiency of these crops was 3.49 and 3.08%. Of the Russian hybrids, the most productive were Cascade 195 SV (Rossoshhybrid), ZP 190 SV and Voronezh 158 (Golden ear) with a green mass yield of 44.8 - 49.0 t/ha, absolutely dry 9.10 – 10.7 t/ha.

1. Introduction

Corn (Zéa máys L.) is an annual, monocotyledonous, dioecious herb of the Bluegrass family (Poaceae) with \( \text{C}_4 \) photosynthesis type [1], a culture of versatile use [1, 2, 3]. The biological characteristics of this crop and its modern hybrids allow to form high yields even in the northern regions including the Tver region of the Russian Federation. [4, 5].

The variety (hybrid) is of a great importance in getting high yields and quality of production [6, 7, 8]. The difference in the studied hybrids yield in several experiments reached 200-300% or more. In recent years, foreign breeding hybrids have become widespread in the agricultural market [9, 10], including genetically modified [11]. A further increase in corn hybrids yield will require an increase in plant density, in the efficiency of nitrogen use and selection – in order to to enhance the plants efficiency under the impact of these factors [12]. Currently, agricultural producers need to choose hybrids that are more adapted to specific agro-climatic conditions. This requires research in a specific region.

The research aim was to identify the most productive domestic and foreign hybrids, allowing to get 60-80 t/ha of green mass with ears of milky-wax ripeness in the Upper Volga region. Methods. The studies were carried out in 2019 on soddy-podzolic well-cultivated soil formed on cover loam in the crop rotation of Skopa Ltd. in the Sonkovsky district of the Tver region (Russia). 34 hybrids of corn were studied (table 1).
Table 1. Characteristics of the studied corn hybrids.

| No. | Variety (Hybrid) | Manufacturers | FAO |
|-----|-----------------|---------------|-----|
| 1   | MAS 18L         | Mas Seeds     | 200 |
| 2   | MAS 14G         |               | 190 |
| 3   | MAS 10A         |               | 160 |
| 4   | MAS 15T         |               | 200 |
| 5   | Zeta 110S       |               | 110 |
| 6   | Zeta 140S       |               | 140 |
| 7   | ELAMIA          | LABOULET      | 210 |
| 8   | Zeta 115S       | (France)      | 115 |
| 9   | Silicia         |               | 170 |
| 10  | Zeta 105S       |               | 95  |
| 11  | Lg 2195         |               | 190 |
| 12  | Nikita          |               | 260 |
| 13  | Lg 30179        | LimaGrain     | 170 |
| 14  | Lg 30189        | (France)      | 180 |
| 15  | Lg 30215        |               | 200 |
| 16  | Lg 31233        |               | 230 |
| 17  | Lg 31235        |               | 240 |
| 18  | Competence      | KWS           | 200 |
| 19  | Cromwell        | (Germany)     | 180 |
| 20  | Corypheus       |               | 190 |
| 21  | Clifton         |               | 175 |
| 22  | SILVINIO        |               | 220 |
| 23  | ZP 165MV        |               | 160 |
| 24  | ZP 153MV        |               | 150 |
| 25  | ZP 200SV        | “KKZ Golden Ear” Ltd. | 200 |
| 26  | ZP 190SV        | (Russia)      | 190 |
| 27  | Cascade 195SV   |               | 190 |
| 28  | Cascade 166ASV  |               | 160 |
| 29  | Voronezh 158    |               | 160 |
| 30  | Cascade 195SV   |               | 190 |
| 31  | Voronezh 160    | "Rossosh hybrid” Ltd. | 160 |
| 32  | Voronezh 158    | (Russia)      | 160 |
| 33  | Cascade 166SV   |               | 170 |
| 34  | Voronezh 175ASV |               | 180 |

The predecessor of corn in the experiment was spring wheat in the crop rotation link: potatoes – barley – spring wheat. 90 t/ha of liquid manure was applied under corn. The lack of NPK in manure for the planned yield (80 t/ha) was compensated with potash fertilizers (sulphate of potash magnesia, 1 c/ha), nitrogen-phosphous-potassium fertilizer (50 kg/ha) and liquid complex fertilizers (LCF) (30 kg/ha) in rows when sowing, as well as liquid fertilizer UAN (urea-ammonium nitrate, 1 c/ha) as topdressing. The main soil cultivation was carried out in spring by deep disking (16-18 cm) with disc harrow DV-1500, before sowing – cultivation with harrowing and leveling. The corn was sowed 15.05.2019 with seeder Ritm-1MT, seeding rate (seed units, SU) 80 thousand/ha. The care consisted of treating crops with MaisTer Power herbicide (1.35 l/ha) and fertilizing with UAN. Inter-row treatments were not applied due to the high effectiveness of herbicides. The harvest was registered 25.09.2019.

During the research, the density of standing, field germination, preservation, plant height, structure and quality of the crop, general and dry matter yield per hectare were determined according to the method of Z. Usanova [13].

Weather conditions in 2019 were characterized by higher temperatures in May and the first half of June, combined with a moisture deficit and cold weather in July and the first decade of August (in July, the air temperature was 2.7 °C below normal, in the first decade of August – 5.2 °C below normal) with
precipitation of 143 and 364 % of normal. In general, for the period from sowing to harvesting, the temperatures sum was 1871.6 °C (that is 23.8 °C below normal), the precipitation sum was 344 mm (120% of normal). The hydrothermic index (according to Selyaninov) was 1.82 in 2019, at norm of 1.50. During the grain filling, the heat and moisture supply of corn crops was satisfactory.

The demand of corn for heat in 2019 in all development periods corresponded to the biological minimum, but was significantly lower than the ecological optimum, especially during the generative organs formation, intensive growth, flowering and ripening [14]. During these periods, at the optimum of 20–24 °C and18–24 °C, in fact, it ranged from 11.6 to 16.3 and from 10.1 to 14.6 °C. The lack of heat had a negative impact on the grain filling and the ears ripeness.

There is information in the literature that recently created cold-resistant hybrids can stop their growth at temperatures below 6 °C. Therefore, the effective temperature for the corn growth and development is considered higher than +6 °C [15].

2. Results

2.1. Plant development features

It was revealed that of 34 examined hybrids, 14 (41.2%) reached the milky-wax stage of ripeness, 6 (17.6%) – milky ripeness. In the remaining hybrids (41.2%) the grain did not reach the milky state. More ripe ears with a well-formed top formed in hybrids Zeta115S, Lg 30189, Lg 30179, Clifton with FAO number from 115 to 180. The hybrids differed among themselves in seedlings density and field germination. Higher germination density and field germination were noted in hybrids Zeta110S and Silvinio (75.1 thousand/ha and 93.9%). Six hybrids (MAS14G, Silicia, Lg 30189, Competence, Clifton, Corypheus) had a seedling density 64.3–67.9 thousand pieces/ha and field germination 80.4–84.9%. In other hybrids, these indicators were lower and ranged from 42.9 to 60.8 thousand pieces/ha and from 53.6 to 76%. Standing density had a significant impact on yield.

The development of plants in the first month of the growing season was uneven, which was reflected in the growth of plants in height and leaf formation. On 28–30th day after germination (06/27/2019) plant height ranged from 55 cm (Competence) to 86.3 cm (Zeta110S), and number of leaves – from 8.0 (MAS18L) to 11.0 pieces (ZP165MV and Elamia).

2.2. Yield of green and absolutely dry matter

Different biological characteristics of hybrids and their adaptive features influenced the green mass yield. The differences in these characteristics made it possible to identify four groups of hybrids (Tables 2, 3, 4, 5): 1- with the biggest green mass yield (from 91.8 to 71.0 t/ha) with ears of milky and milky-wax ripeness; 2 – with a medium green mass yield (from 66.4 to 50.5 t/ha) with ears not reaching milky ripeness; 3 – with low green mass yield (from 48.0 to 40.1 t/ha) mostly with not filled ears; 4 – with very low green mass yield (from 39.4 to 31.2 t/ha) with ears in a milky-wax and wax ripeness and partially in a watery grain state. The 1st and 2nd groups included 6 hybrids each (17.6% each), the 3rd – 13 (38.2%), the 4th – 9 (26.6%).

The most productive in terms of green and absolutely dry mass yield were hybrids Zeta110S with a green mass yield of 91.8 t/ha, and absolutely dry – 18.9 t/ha, and LG30189, in which these figures were 87.5 and 21.39 t/ha. Their differences lie in the dry matter content in the ears – 20.7 and 24.8%, which is explained by the fact that in the Zeta110S hybrid, the ears were filled with grain up to half the length.

Due to the different ripeness of the ears, the content of absolutely dry matter in them in the studied hybrids ranged from 6.4% (Cromwell) to 32.9% (Corypheus) (Figure 1). The absolutely dry matter yield depended both on its content in the green mass and on the total yield size. The higher dry matter collection per hectare was provided by the hybrids of the 1st productivity group, on average for the group - 18.55 t/ha, and the lowest collection – in the 4th group (7.3 t/ha).

Of the Russian hybrids, the following were distinguished by a higher yield of green and absolutely dry mass: Cascade 166SV (Rossosh hybrid), ZP190SV (Golden Ear), Voronezh 158 (Golden Ear), in
which the green mass yield was 45.0; 49.0; 44.8; absolutely dry – 10.7; 9.5 and 9.1 t/ha, respectively, which was 2.0 times lower than that of the best foreign-made hybrids.

Table 2. Group of varieties with the highest green mass yield (70.0 t/ha and more).

| Variety (hybrid) | FAO | Manufacturer | Yield, t/ha | Content of absolutely dry matter, % | Yield of absolutely dry phytomass, t/ha |
|-----------------|-----|--------------|-------------|-------------------------------------|----------------------------------------|
| Zeta 110 S      | 110 | LABOULET (France) | 91.8        | 16.3 | 20.0 | 20.7 | 20.1 | 18.5 |
| Lg 30189        | 180 | LimaGrain (France) | 87.5        | 24.3 | 24.3 | 24.8 | 24.4 | 21.3 |
| Lg 31233        | 230 |               | 79.1        | 24.5 | 19.8 | 17.2 | 19.0 | 15.0 |
| Lg 2195         | 190 |               | 74.5        | 15.8 | 19.2 | 22.6 | 19.9 | 14.9 |
| Lg 30179        | 170 |               | 73.0        | 20.2 | 22.8 | 26.1 | 23.7 | 17.3 |
| MAS 15T         | 200 |               | 71.0        | 19.6 | 18.7 | 21.5 | 19.5 | 15.0 |
| **Group average** |     |               | **79.5**    | **20.2** | **20.8** | **22.1** | **21.1** | **16.8** |

Table 3. Group of varieties with a green mass yield of 50.0–70.0 t/ha.

| Variety (hybrid) | FAO | Manufacturer | Yield, t/ha | Content of absolutely dry matter, % | Yield of absolutely dry phytomass, t/ha |
|-----------------|-----|--------------|-------------|-------------------------------------|----------------------------------------|
| MAS 14G         | 190 | MAS Seeds (France) | 57.7        | 15.4 | 17.8 | 18.2 | 17.9 | 10.3 |
| Silicia         | 170 | LABOULET (France) | 61.8        | 18.4 | 23.6 | 9.6  | 19.4 | 12.0 |
| ELAMIA          | 210 | LABOULET (France) | 50.5        | 14.2 | 18.1 | 24.8 | 20.0 | 10.1 |
| SILVINIO        | 220 | KWS (Germany)   | 66.4        | 12.2 | 23.7 | 15.0 | 22.1 | 14.7 |
| Competence      | 200 | Golden Ear (Russia) | 62.2        | 22.3 | 23.0 | 9.9  | 18.3 | 11.4 |
| **Group average** |     |               | **59.0**    | **16.0** | **20.2** | **15.1** | **18.7** | **11.1** |

Table 4. Group of varieties with a green mass yield of 40.0–50.0 t/ha.

| Variety (hybrid) | FAO | Manufacturer | Yield, t/ha | Content of absolutely dry matter, % | Yield of absolutely dry phytomass, t/ha |
|-----------------|-----|--------------|-------------|-------------------------------------|----------------------------------------|
| Variety (hybrid) | FAO | Manufacturer | Yield, t/ha | Content of absolutely dry matter, % |
|-----------------|-----|--------------|------------|-----------------------------------|
|                 |     |              | green mass | including ears in leaves and stalks in ears in green mass |
| MAS 18L         | 200 | MAS Seeds (France) | 42.8       | 9.9 23.6 22.3 23.3 10.0 |
| Zeta 105S       | 95  | LABOULET (France) | 43.0       | 9.8 20.7 16.5 19.7 8.5 |
| Lg 30215        | 200 | LimaGrain (France) | 48.0       | 6.2 22.6 12.7 21.3 10.2 |
| Lg 31235        | 240 |                | 46.2       | 18.2 22.9 25.0 23.7 10.9 |
| Nikita          | 260 |                | 40.3       | 16.4 22.8 17.8 20.8 8.4 |
| Corypheus       | 190 | KWS (Germany)  | 40.0       | 16.2 23.4 32.9 27.2 10.9 |
| Zeta 140S       | 140 | LABOULET (France) | 48.3       | 11.4 18.6 11.3 16.9 8.1 |
| Zeta 115S       | 115 |                | 44.8       | 11.6 20.6 19.9 20.4 9.1 |
| Clifton         | 175 | KWS (Germany)  | 44.7       | 12.8 23.9 20.3 22.9 10.2 |
| Voronezh 158    | 160 | Golden Ear (Russia) | 45.0       | 10.1 24.7 20.6 23.8 10.7 |
| Cascade 166ASV  | 160 | Rossosh hybrid (Russia) | 42.1       | 11.3 23.0 10.6 19.7 8.3 |
| Cascade 195SV   | 190 | Golden Ear (Russia) | 40.1       | 9.8 19.0 21.2 19.6 7.8 |
| Group average   |     |              | 44.2       | 11.7 21.8 20.0 21.4 9.4 |

Table 5. Group of varieties with a green mass yield of 40,0 t/ha and less.
2.3. PAR efficiency factor of crops

In connection with different productivity, the studied corn hybrids differed in PAR (photosynthetic active radiation) efficiency factor (table 6). Hybrid Lg 30189 was characterized by a higher PAR efficiency (3.49%), which was 2.7 times higher than that of the widely used Russian hybrid Cascade 195SV. The data obtained confirm our conclusions on the Lg 30189 hybrid about its greatest use of the incoming photosynthetic active radiation in the Tver region [4]. The best Russian hybrids in 2019 had PAR efficiency of 1.5–1.7%.

Table 6. PAR efficiency of different corn hybrids, 2019, %.

| Variety (hybrid) | FAO | Manufacturer         | Yield, t/ha       | PAR*, % |
|-----------------|-----|----------------------|-------------------|---------|
|                 |     |                      | green mass        | dry mass |         |
| Zeta 110C       | 110 | LABOULET (France)    | 91.8              | 18.5    | 3.08    |
| Lg 30189        | 180 |                      | 87.5              | 21.3    | 3.49    |
| Lg 31233        | 230 | LimaGrain (France)   | 79.1              | 15.0    | 2.45    |
| Lg 2195         | 190 |                      | 74.5              | 14.9    | 2.43    |
| Lg 30179        | 170 |                      | 73.0              | 17.3    | 2.89    |
| MAS 15T         | 200 | Mas Seeds (France)   | 71.0              | 13.8    | 2.25    |
| ZP 190SV        | 190 | Golden Ear (Russia)  |                   | 49.0    | 9.5     | 1.55    |
| Voronezh 158    | 160 |                      |                   | 44.8    | 9.1     | 1.48    |
| Cascade 166SV   | 170 | Rossosh hybrid       |                   | 45.0    | 10.7    | 1.74    |
| Cascade 195SV   | 190 | (Russia)             |                   | 40.1    | 7.8     | 1.27    |

* The arrival of PAR was determined by the radiation balance (R) in the Sonkovsky district of the Tver region.

3. Conclusion

In the North-East of the Tver region (Russia, Sonkovo), with effective temperatures sum (more than 10 °C) 1845 °C, at temperatures lower than the ecological optimum by 8.0 °C in the vegetation period, and 8-9 °C lower in the ripening period, in 14 hybrids (41.2%) the ears reached the milky-wax ripeness stage. The most ripe well-formed ears were in hybrids Zeta115S, Lg 30189, Lg 30179, Clifton with FAO number 115–180.
The variety of hybrids (34 pcs.) differed in the field germination of seeds and the density of standing for harvesting, which influenced the yield. Eight hybrids (23.5%) with a higher field germination (80.4–93.9%) were distinguished by a higher density of the state for harvesting (64.3–75.1 thousand/ha) and yield (50.5–91.8 t/ha of green mass).

The following hybrids were characterized by a high dry matter content in the ears (%): Coryphaeus (32.9), Clifton (28.9), ZP190SV (28.4), Lg 30179 (26.1), Zeta115S (25.6), Lg 30189 and Elamia (24.8), MAS 100A (24.4).

By productivity, 4 groups of hybrids with an average green and dry matter yield (t/ha) were identified: 1–6 hybrids (17.6%) 79.48 and 18.55; 2–6 hybrids (17.6%) 58.97 and 11.1; 3 – 13 hybrids (38.2%) 41.1 and 9.4; 4–9 hybrids (26.6%) 31.2 and 7.3.

The most productive were hybrids Lg 30189 and Zeta110S, which accumulated green mass yield 87.5 and 91.8 t/ha, absolutely dry 21.39 and 18.52 t/ha. These hybrids are distinguished by the highest productivity of their crops, which in Lg30189 reached 3.49% of PAR efficiency, in Zeta110S – 3.8% of PAR efficiency.

Of the Russian hybrids, the most productive and having a higher sowing productivity were: Cascade 166 SV (Rossosh hybrid), ZP 190SV and Voronezh 158 (Golden Ear), their green mass yield ranged from 44.8 to 49.0 t/ha, absolutely dry mass yield – from 9.10 to 10.70 t/ha, and the PAR efficiency of sowing was from 1.48 to 1.74%.

Hybrid Lg 30189 (LimaGrain, France) was the leader in yield and quality of green mass.

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