Festulolium seed productivity depending on sowing methods and seeding rates

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Abstract. The effectiveness of animal husbandry depends on stable provision of animals with high-quality and inexpensive feed. The most affordable source of feed is perennial grasses. New varieties of forage grasses with improved characteristics are an important reserve for fodder production. The intergeneric festulolium hybrid is a valuable forage crop for field and meadow grass sowing which can be used for green fodder, hay, silage, haylage, cultivated hayfields and pastures. The scientific development of cultivation techniques is required to ensure high and sustainable seed yields. An important element of the cultivating technology is the rate of sowing seeds and the method of sowing. In the studies conducted in 2006–2009, the biological characteristics and seed productivity of festulolium were studied at different seeding rates. According to the results of the studies, it can be noted that sowing of festulolium by traditional (15 cm) or inter-row (30 cm) methods at a seed rate of 6.0 kg / ha allows for the formation of a sparse and weakly lodging grass stand. The photosynthetic apparatus of festulolium assimilated most productively when using conventional and inter-row methods of sowing at seeding rates of 6.0 and 9.0 kg/ha, as evidenced by the maximum value of the photosynthetic potential - 1029-1090 thousand m²×day/ha. Excessive thickening of crops (12.0 kg/ha) adversely affects the formation of elements of the crop structure and reduces their productivity. It was found that the highest yield of festulolium seeds with the traditional (604.3 kg/g) and inter-row (652.3 kg / ha) sowing methods were obtained at a seeding rate of 6.0 kg / ha and plant density of 130–133 pcs / m².

1. Introduction

In seed production of perennial cereal grasses, one of the most important conditions ensuring the seed yield is optimization of the plant nutrition area which depends on the density of a seed grass stand, biological characteristics of a variety, soil and climatic conditions of a particular area, seeding rates and methods [1, 2, 3, 4, 5, 6].

In the CEC, perennial herbs play a leading role in solving the problem of obtaining feeds containing protein, essential amino acids and vitamins. They solve the problem of high-quality, cheap feed, reduce soil erosion processes, and reduce the human impact on the environment. It is important to expand the range of forage crops by using new fodder grasses with the best properties [7, 8]. One of promising fodder crops is festulolium (× Festulolium F. Aschers. Et Graebn.) obtained using intergeneric hybridization of the genera Lolium sp. and Festuca sp. Festulolium is a valuable forage for field and meadow grass planting, which can be used for green fodder, hay, silage, haylage, as well
as when creating cultivated hayfields and pastures. Its advantages are good hiding, high sugar content and high cold resistance [9, 10, 11, 12, 13, 14, 15].

It is necessary to develop methods for cultivating festulolium aimed at using its biological potential and obtaining high and sustainable seed yields.

Important elements of the cultivation technology are the seeding rate and the sowing method which determine the area of nutrition and density of plant standing. With a small plant stand area, the competition of plants for moisture and nutrients intensifies, which causes a decrease in productivity of photosynthesis. The large areas also have a negative effect [16, 17, 18, 19].

The study and selection of optimal sowing methods and seeding rates determined the goal of our research.

2. Materials and methods

The experiments were conducted in 2006–2009 by the Department of Soil Management, Crop Science and Plant Protection of Voronezh State Agrarian University on the fields of the Training, Research and Technological Center ‘Agrotechnology’ (N51.7140416 E39.21545371).

The soil was leached medium loamy chernozem containing 4.56–5.50% of humus, 78–129 g/kg of labile phosphorus (P$_2$O$_5$), 109–118 mg/kg of exchangeable potassium (according to Chirikov), pH$_{salt}$ was from 4.9 to 5.1, the total absorbed bases was from 21.3 to 22.2 mg–eq. per 100 g of soil, and the degree of base saturation was of 74–86%.

The weather conditions varied significantly, which allowed us to give an objective assessment of the methods of sowing and seeding rates. As a precursor for festulolium varieties VIK-90, the vetch oat mixture was used.

The soil preparation method was generally accepted for the creation of seed grass stands of perennial grasses in the Central Chernozem Region. Using the traditional (15 cm) and inter-row (30 cm) sowing methods, different seeding rates of festulolium (3.0; 6.0; 9.0; 12; 0 kg / ha) were studied. The accounting plot area was 20 m$^2$. The experiment was repeated 4 times, the placement of options was randomized. Festulolium seed crops were harvested by the Sampo-130 combine with a seed moisture content of 40–45%, taking into account the crop plot and its subsequent conversion to 12% humidity and 100% seed purity. Field observations taking into account density, wintering, and seed yield were carried out in accordance with the generally accepted methods [20].

3. Results and discussion

Seed germination is an important indicator that determines the density of seedlings, plant growth and development, yield and quality of seeds. Depending on the sowing method and seed seeding rate, the field germination of festulolium seeds varied from 60.9% to 68.9%. The smallest field germination of seeds (60.9% with a traditional sowing method and 62.7% with an inter-row sowing method) was at a seeding rate of 3.0 kg/ha. The highest rates of field germination (66.2–68.9%) were observed at seeding rates of 9 and 12 kg/ha (Table 1).

The highest seedling density was obtained at high seeding rates using both methods of sowing. At the same time, the row spacing did not significantly affect this indicator. Thus, there is a direct relationship between the seed density and the seed rate.

In the first year, the death of plants did not exceed 7–11%. There was a slight increase in plant deaths with an increase in seeding rates due to the fact that the closer the plants are placed in a row, the stronger their mutual allelopathy and competition for moisture, light and nutrients.

The possibility of using new varieties is determined by their frost resistance. An integrated indicator is the percentage of wintering. Festulolium has a high degree of plant safety in the conditions of the forest-steppe zone of the Central Chernozem Region. The most favorable conditions for wintering festulolium developed in 2006-2007. On average, at a seeding rate of 3.0 kg / ha using an inter-row sowing method, 92.0% of plants survived. At a seeding rate of 12.0 kg / ha, the survival rate was 87.3%. The average survival rate was 82.1–92.0%.
Table 1. The development of festulolium in the year of grass stand development depending on the methods of sowing and seeding rates (2006-2008)

| Sowing method | Seeding rate, kg/ha | Field germination, % | Density of seedlings, pcs/m² | Death of plants during the growing season, % | Number of plants, pcs/m² | Plant survival rate, % |
|---------------|---------------------|----------------------|-----------------------------|---------------------------------------------|--------------------------|----------------------|
| Traditional 1 (15 cm) | 3                   | 60,9                 | 63,0                         | 6,9                                         | 58,9                     | 53,3                 | 90,5                |
|               | 6                   | 64,0                 | 132,5                        | 9,0                                         | 121,6                    | 105,8                | 87,0                |
|               | 9                   | 66,5                 | 206,5                        | 10,3                                        | 187,1                    | 157,2                | 84,0                |
|               | 12                  | 68,9                 | 285,1                        | 10,7                                        | 257,6                    | 211,5                | 82,1                |
| Inter-row (30 cm) | 3                   | 62,1                 | 64,3                         | 7,2                                         | 60,0                     | 55,2                 | 92,0                |
|               | 6                   | 62,7                 | 129,8                        | 8,5                                         | 119,6                    | 109,7                | 91,7                |
|               | 9                   | 66,2                 | 205,3                        | 10,0                                        | 186,7                    | 163,9                | 87,7                |
|               | 12                  | 68,0                 | 281,2                        | 11,0                                        | 253,3                    | 221,0                | 87,3                |

HCP_{05} i.r. – 9.9…22.8 – 10.3…22.0 9.9…21.0 –
HCP_{05} factor A – 5.0…11.4 – 5.1…11.0 4.9…10.5 –
HCP_{05} factor B – 7.0…16.1 – 7.3…15.5 7.0…14.8 –

We found that the onset and duration of the phenological phases do not coincide in time with more thickened options. With an increase in the seeding rate, the time required for the development phases decreases by 2–3 days. This is more evident when using the inter-row sowing method. During the second year, at a seeding rate of 12.0 kg / ha, the number of days from the spring growth to the shooting is 32–33, while at a seeding rate of 3.0 kg / ha, it is 34–36.

The start of the earing phase at the maximum seeding rate (12.0 kg / ha) occurs 3–4 days earlier than at the minimum rate (3.0 kg / ha). The earing phase lasts for 15–17 days; on the 64–67th day, the flowering phase begins.

The greatest differences in the duration of the phases appeared during the ripening period. The duration of full ripeness was the longest (103–105 days) at the seeding rates of 3.0 and 6.0 kg / ha. With an increase in plant density per unit area, the seed ripening period was reduced by 2–3 days. Using the traditional method of sowing, the ripening period was 102–105 days, and using the inter-row method, it was 102–107 days.

In our studies, the method of sowing and the rate of seeding had a significant effect on the height of the plants. As a rule, with an increase in the seeding rate, the length of the generative shoots and the height of the grass stand increase for the traditional and inter-row methods. At a seeding rate of 3.0 kg / ha, the length of the generative sprouts of festulolium was 41.5–45.4 cm; at a seeding rate of 12.0 kg / ha, it was 47.1–51.0 cm.

With an increase in the seeding rate, an increase in the lodging was observed. In the flowering phase, the greatest degree of lodging (10.6–12.1%) was observed at a high seeding rate (12.0 kg / ha) when using the traditional method of sowing.

With the growth of festulolium plants, their leafiness increased. In the flowering phase, this indicator reached its highest values (53.0–63.5%). The high foliage of the festulolium plant was formed at low seeding rates due to the fact that in a rarefied herbage, plants developed in more favorable conditions and had access to light, moisture and mineral nutrition.

The foliage of plants is greatly influenced by the amount of precipitation. In humid 2008, the foliage of plants in the flowering phase was the highest (58.5–68.9%), and in a less humid year (2009), this indicator was lower by 11.9–15.2%
The area of the leaf surface depended on the number of plants per unit area. In the flowering phase, when the leaf area reaches its maximum values, the difference between the variants became more noticeable (Table 2).

Table 2. Indicators of photosynthetic activity of festulolium depending on the sowing method and the seeding rate (2007-2009)

| Sowing method       | Seeding rate, kg/ha | The abundance of plants, % | Area of leaves thousand m²/ha | Net photosynthesis productivity, g/m² × day | Photosynthetic potential, thousand m² × day / gb |
|---------------------|---------------------|-----------------------------|-------------------------------|---------------------------------------------|-------------------------------------------------|
| Traditional row (15 cm) | 3                   | 58,6                        | 28,7                          | 4,74                                        | 736                                             |
|                     | 6                   | 60,0                        | 40,0                          | 3,32                                        | 1029                                            |
|                     | 9                   | 54,4                        | 38,6                          | 2,98                                        | 1023                                            |
|                     | 12                  | 53,0                        | 37,0                          | 2,69                                        | 1009                                            |
| Inter-row (30 cm)   | 3                   | 61,8                        | 29,7                          | 4,97                                        | 757                                             |
|                     | 6                   | 63,5                        | 42,5                          | 3,59                                        | 1090                                            |
|                     | 9                   | 57,3                        | 40,2                          | 3,20                                        | 1070                                            |
|                     | 12                  | 56,8                        | 38,7                          | 2,98                                        | 1052                                            |
| HCP05 i.r.          | 3,4…4,2             | 6,3…8,4                     | 0,99…1,26                     | –                                           | –                                               |
| HCP05 factor A      | 1,7…2,1             | 3,1…4,2                     | 0,50…0,63                     | –                                           | –                                               |
| HCP05 factor B      | 2,4…3,0             | 4,4…5,9                     | 0,70…0,89                     | –                                           | –                                               |

a in the flowering phase.
b total for the vegetation period.

The largest photosynthetic surface (40.2–42.5 thousand m² / ha) was formed in the second year at a seeding rate of 6.0 and 9.0 kg / ha when using a traditional sowing method - 3.8 and 12.7 thousand m² / ha more than at a seeding rate of 12.0 and 3.0 kg / ha.

During the growing season, the photosynthetic potential was 736–1029 and 757–1090 thousand m² × day / ha for the traditional and inter-row sowing methods. The calculation of a linear correlation showed a strong relationship between the sum of the photosynthetic potential during the growing season and the seed productivity of festulolium (r = 0.831–0.861).

The assimilation apparatus of festulolium worked most productively when using the traditional and inter-row methods at a seeding rate of 3.0–6.0 kg / ha, as evidenced by the maximum value of the net productivity of photosynthesis - 3.32–4.97 g / m² × day. With an increase in the seeding rate, the value of this indicator decreased; for the most thickened option (12.0 kg / ha), it amounted to 2.69–2.98 g / m² × day.

It has been established that the largest seed productivity can be achieved in moderately sparse grass stands. In such crops, a larger number of generative shoots, spikelets and seeds are formed in the ear (Table 3).

In the second year, the number of generative shoots was 482-77 pieces/m². Excessive thickening negatively affected the crop structure. The row spacing had an impact on their number. When using both methods of sowing with a decrease in the seeding rate, the number of generative shoots increased. In the second year, at a seeding rate of 12.0 kg / ha, the number of generative shoots was 674–685 pcs/m², and when the seeding rate was reduced to 6.0 kg / ha, their number increased to 747–777 pcs / m². This pattern was observed in subsequent years.

With an inter-row sowing method (30 cm), there was an increase in the number of generative shoots at all seeding rates. The method of sowing is of less importance in the seed production of festulolium compared to the seeding rates and weather conditions during the growing season.
The best conditions for festulolium seeds are formed in inter-row grass stands at a seeding rate of 6.0 kg / ha – 777 generative shoots with a high number of seeds (64 pcs.). In sparse crops, favorable microclimate conditions are formed for cross pollination, fruit formation and seed ripening. The highest seed productivity of festulolium was obtained at a seeding rate of 6.0 kg / ha and stand density of 130–133 pcs / m$^2$, when using the traditional sowing method, the seed yield was 604.3 kg / ha; when using the inter-row sowing method, the seed yield was 652.3 kg/ha. In sparse (the seeding rates was 3.0 kg/ha) and thickened (seeding rates were 9.0 and 12.0 kg/ha) areas, the seed yield decreased due to a decrease in the number of generative shoots per unit area and worsening conditions for pollination of flowers and formation of seeds in lodged grass stands (Table 4).

| Sowing method (A factor) | Seeding rate, kg/ha (B factor) | Spike length, cm | Number of generative shoots, pcs / m$^2$ | Number of spikelets in the ear, pcs. | Number of seeds in one ear, pcs. |
|-------------------------|--------------------------------|-----------------|------------------------------------------|----------------------------------|----------------------------------|
| Traditional row (15 cm) | 3                              | 17,9            | 482,2                                    | 18,1                             | 68,3                             |
|                         | 6                              | 17,3            | 746,6                                    | 17,5                             | 59,4                             |
|                         | 9                              | 16,7            | 700,9                                    | 17,0                             | 55,9                             |
|                         | 12                             | 16,7            | 674,2                                    | 16,4                             | 53,7                             |
| Inter-row (30 cm)       | 3                              | 18,2            | 532,0                                    | 19,1                             | 70,9                             |
|                         | 6                              | 17,5            | 777,4                                    | 18,0                             | 63,7                             |
|                         | 9                              | 17,0            | 736,7                                    | 17,8                             | 60,0                             |
|                         | 12                             | 16,8            | 685,5                                    | 17,1                             | 58,5                             |
| HCP$_{0.05}$i.r.        |                                | 1.0...1.1       | 14,1...31.7                              | 0.9...1.3                        | 2.9...6.2                        |
| HCP$_{0.05}$ factor A   |                                | 0.5...0.6       | 7.0...15.8                               | 0.5...0.7                        | 1.4...3.1                        |
| HCP$_{0.05}$ factor B   |                                | 0.7...0.7       | 10.0...22.4                              | 0.7...0.9                        | 2.0...4.4                        |

| Sowing method (A factor) | Seeding rate, kg/ha (B factor) | 2007 | 2008 | 2009 | on average |
|-------------------------|--------------------------------|------|------|------|------------|
| Traditional (15 cm)     | 3                              | 498.6| 463.7| 455.3| 472.5      |
|                         | 6                              | 583.4| 638.5| 591.1| 604.3      |
|                         | 9                              | 567.7| 592.0| 527.3| 562.3      |
|                         | 12                             | 536.0| 506.0| 521.6| 521.2      |
| Inter-row (30 cm)       | 3                              | 492.6| 488.9| 492.2| 491.2      |
|                         | 6                              | 661.1| 688.1| 607.9| 652.3      |
|                         | 9                              | 610.3| 633.8| 568.3| 604.1      |
|                         | 12                             | 591.5| 550.1| 545.5| 562.3      |
| HCP$_{0.05}$i.r.        |                                | 24.0  | 22.3 | 32.6 | –          |
| HCP$_{0.05}$ factor A   |                                | 12.0  | 11.2 | 16.3 | –          |
| HCP$_{0.05}$ factor B   |                                | 17.0  | 15.8 | 23.0 | –          |

Seeds had high sowing qualities: germination energy – 73–86%, laboratory germination – 84–95%, which meets GOST R 52325–2005. With an increase in the seeding rate, a decrease in the mass of 1000 seeds was observed for traditional and inter-row sowing method. If at a seeding rate of 3.0 kg / ha it was 2.97–3.13 g, at a rate of 12.0 kg / ha, it was 2.73–2.80 g.
4. Conclusion
Thus, the creation of Festulolium seed stands using a traditional or row-wise way at a reduced seeding rate of 6.0 kg / ha increases seed productivity and reduces seed consumption 1.5–2.0 times. However, this requires careful preparation of the soil and seeds for sowing. It is necessary to choose effective weed control measures.

References
[1] Deleuran L, Gislum R and Boelt B 2009 Cultivar and row distance interactions in perennial ryegrass Acta Agriculturae Scandinavica 59 335–341
[2] Han Y, Hu T and Mao P 2016 Smooth bromegrass seed yield and yield component responses to seeding rates and row spacings in two climates Journal Plant Production Science 19 (3) 381–388
[3] Koeritz E, Watkins E and Ehike N 2015 Seeding Rate, Row Spacing, and Nitrogen Rate Effects on Perennial Ryegrass Seed Production Crop Science 55 2319–2333
[4] Kays S and Harper J L 1974 The Regulation of Plant and Tiller Density in a Grass Sward The Journal of Ecology 62 97–105
[5] Szczepanek M 2015 Emergence and seed yield of redtop as affected by row spacing and seeding rate Acta Agriculturae Scandinavica, Section b — Soil & Plant Science 65 537–543
[6] Yunhua H, Wang X and Hu T 2013 Effect of Row Spacing on Seed Yield and Yield Components of Five Cool–Season Grasses Crop Science 53 (6) 2623–2630
[7] Obraztsov V, Shchedrina D and Kadyrov S 2018 Film agents as an effective means of reducing seed shattering in Festulolium Agronomy Research 16 (5) 2130–2136
[8] Perepravo N I 2001 Features of seed production of the new fodder crop Festulolium Selection and seed production 4 28–31
[9] Kutuzova A A, Zotov A A and Kuleshov G F 2000 Promising directions for the creation of cultural pastures in Russia Feed production 8 12–15
[10] Perepravo N I 2012 The problems of seed production in the North Multifunctional adaptive feed production: materials of the Intern. conf. 72–76
[11] Obraztsov V N and Fedotov V A 2013 Protection of seed crops of festulolium from weeds in the forest-steppe of the Central Chernozem Region Agriculture 6 18–20
[12] Barnes B D, Kopecky D and Lukaszewski A J 2014 Evaluation of turf–type interspecific hybrids of meadow fescue with perennial ryegrass for improved stress tolerance Crop science 54 (1) 355–365
[13] Kivato A, Akiyama Y and Ueyama Y 2015 Variability of genomic constitutions of festulolium (Festuca × Lolium) within and among cultivars Grassland science 61 (1) 15–23
[14] Kvasnovsky M, Klusonova I and Hodulikova L 2014 Evaluation of the suitability of grass species for dry conditions 21st International PhD Students Conference Mendel Univ 68–71
[15] Schiavon M, Green R and Baird J 2014 Drought Tolerance of Cool–Season Turfgrasses in a Mediterranean Climate European journal of horticultural science 79 (3) 175–182
[16] Gasiev V I 2016 Festulolium productivity depending on the norms and methods of sowing Izvestia of Gorsk State Agrarian University 53 (2) 41–46
[17] Perepravo N I 2010 State and prospects of development of seed production of forage grasses Fodder production 8 30–32
[18] Kravtsov V V and Nadimov N V 2013 Festulolium variety for hayfields and pastures Fodder production 10 19
[19] Deleuran L, Gislum C R and Boelt B 2010 Effect of seed rate and row spacing in seed production of Festulolium Acta agriculturae scandinavica, Section b — Soil & Plant Science 60 (2) 152–156
[20] Methodological Instructive Regulations on the Conducting of Research in Seed Production of Perennial Grasses 1989 (Moscow: VIK)