Effect of new cover crops and sowing dates on growth, development and yield of awnless bromegrass in Western Siberia

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Abstract. Research carried out in the northern forest-steppe of the Western Siberia on leached chernozem showed that of all the studied dates of sowing bromegrass under the cover of spring crops, the maximum yield was obtained when sowing from 10 to 20 July under the cover of a mixture of oats with rapeseed or winter rye - 8.5 and 7.1 t/ha of dry weight respectively. This is achieved by controlling the weeds before sowing when cultivating the field and creating optimal conditions for the development of forage crops, which affects the safety of young bromegrass plants after wintering - 84-97%. The use of Sudan grass as a cover crop when sown between 15 and 25 May results in up to 49% loss of bromegrass from the grass stand, but due to the early harvest of the cover crop, bromegrass has time to accumulate enough spare nutrients for successful overwintering. The average annual yield of dry mass is 5.0 t / ha. Sowing bromegrass from 10 to 20 June under cover mixtures of bromegrass with rapeseed or millet with rapeseed suppresses both the cover crops and the weeds, which have the most favorable growth conditions at this time. After harvesting, bromegrass forms a grass stand with a dry matter yield of 5.8 t/ha.

1. Introduction
The vast majority of the literature on the technology of perennial grasses shows that the issues of grass sowing under cover of forage and cereal crops are sufficiently well studied and covered in the special literature. In Siberian conditions, perennial grasses are sown under cover in the spring [1-3]. In summer, bluegrass grasses are sown without cover - until early August [4-6].

Advocates of spring and summer sowing justify their choice as follows: with spring sowing in May and June, there is a high probability of soil drought and return frost, which has a negative effect on the friendliness of perennial grass seedlings and their growth dynamics. As a result, these crops become overgrown with weeds. In order to control weeds, their place in the cenosis is taken by annual fodder crops (cover crops), which are mowed when they reach mown maturity and are used to feed the livestock. This solves another problem: the field is not empty when perennial grasses are planted, but gives production in the year of sowing.

During the summer sowing period for weed control, the soil is prepared using the steam type before sowing, as a result of the creation of optimal conditions, weeds emerge en masse, which are destroyed by cultivation. The sowing itself takes place after precipitation has fallen, which improves the friendliness of the emergence of seedlings.
In fodder production, along with the traditional ones (oats, barley, peas), as a result of successful selection work, other fodder crops have been introduced and effectively used, which include Sudan grass and spring rapeseed. In the very near future, mixed crops of rapeseed with Sudan grass or millet will become widespread [7-9]. These mixtures will be used for silage preparation. The advantages of such crops are that they allow you to expand both the territorial boundaries of the cultivation of mixtures and to obtain higher yields. Sudan grass and millet are drought-resistant crops, spring rape, when sown in late summer, forms a fodder mass used after frost as a green top dressing. These qualities of crops can also be used when planning a feed conveyor.

The use of single-species and mixed crops of the above annual crops as cover crops for perennial grasses when sowing in spring, summer and late summer has not been studied at all. With regard to spring and summer sowing dates (June 10-20), there is some confidence in a positive result. The main problem here is to get seedlings.

Undercover sowing of perennial grasses in late summer periods (July 10-20) does not give firm guarantees of a favorable outcome. Here, as in the previous case, it is important to get seedlings quickly. The likelihood of obtaining friendly seedlings is very high, since sowing is actually carried out in pairs and under autumn precipitation. For the successful overwintering of grasses, the length of the “germination - the end of the growing season is decisive in this case. The longer it is, the better the grass will be prepared for overwintering.

Late summer sowing under cover of winter rye is an exploratory option. Its results cannot yet be predicted. According to the literature, perennial grasses have been tried under cover of winter rye in the spring, building optimal crop rotations with it [10, 11, 12]. The rye in this case grew intensively and severely oppressed the perennial grasses. The only case of late summer sowing of perennial grasses under winter rye noted in the scientific literature is in the irrigated lands of Armenia. The retengrass overwintered safely under the cover of winter rye [13].

2. Materials and methods

The experiment was laid on the scientific and experimental base of the Siberian Research Institute of Forage, located in the forest-steppe of the Ob region on medium loamy, leached chernozem.

The forecrop was cereals. Sowing was carried out at the dates according to the scheme of experiments by seeder SN-16 in a row method. Cover crops were sown before bromegrass sowing across the variants. The seeding rate of bromegrass - 6 mln.pcs./ha. The seeding rates of the cover crops were reduced by 30%.

Meteorological conditions in 2006 were characterized as arid with an uneven distribution of precipitation during the growing season. May-July was characterized by increased air temperatures with a simultaneous deficit of precipitation. Significant rainfall occurred only in the second decade of June (178% of the long-term average). August was generally close to the norm in terms of air temperature, but with an excess of up to 203% of precipitation over the norm.

The 2007 growing season was generally favorable for the growth and development of perennial grasses. The first and second ten-day periods of May were warmer by 3.0-4.10C, with precipitation 6 and 85% above the norm. The third ten-day period of May - second June was characterized by low temperatures (1.1-5.50C below normal) and increased moisture content (120-227% of the norm). The weather was warm from the third decade of June until early August, when mean precipitation was 23.1 mm per decade, 4.6% below the long-term average.

From the second decade of August to the end of September, there was an unfavorable period in terms of heat and moisture availability. The excess temperature was 2.3-4.20C, and precipitation was 54-73% less than normal.

The growing season of 2008 was generally favorable for grass growth in terms of air temperature. Thus, from April to August the average monthly temperature was 0.6-2.0 OC above the norm. The picture is somewhat different with regard to moisture availability. While in April and June precipitation amounted to 160 and 116% of the norm, in July and August it was only 56 and 76%, respectively, indicating that the second half of the summer was arid.
In 2009, favorable conditions for the growth and development of perennial grasses were repeated: in May and August there was an excess of 1.8 and 0.5 °C above the mean annual air temperature, respectively. June and July were colder than the long-term average by 3.1 and 0.8 °C, but the overall temperatures were optimum, ranging from 11.8 to 19.7°C.

The rainfall in May was 55% of the norm, but due to the winter reserves the grasses did not feel the lack of it, and the traditional Siberian June drought was replaced by an excess of 52% of the average annual norm and in July by 57% of the norm. Thus, the grasses felt quite comfortable, which had a positive effect on their yields later on.

Weather conditions in 2010 were characterized by low temperatures and moisture deficit. During May the rainfall was 60.2 mm or 158% of the norm, in June-August only 36-75%. Temperatures during these months were 1.6-1.80°C below the long-term average. In general, the year was unfavorable for growth and development of perennial grasses, which had a negative impact on their yield in both the first and second cuttings.

### Experiment scheme

| Sowing date and time | Cover crop | Covercropuse | Covercropharvestingphase |
|----------------------|------------|--------------|--------------------------|
| Spring               |            |              |                          |
| May 15-25            | Sudan grass| Greenfodderorhay | Ear formation         |
| Summer               | Sudan grass + Rapeseed| Haylage | The beginning of rapeseed fruit formation |
| June 10-20           | Millet + Rapeseed | Silage | The beginning of rapeseed flowering. |
| Late summer          | Rapeseed   | Green feed   | Rye - in the spring of next year in the earing phase. |
| July 10-20           | Oat + Rapeseed |        |                          |
|                      | Winter rye |              |                          |

3. **Results and discussion**

Sowing bromegrass under cover of fodder crops with reduced seeding rates showed that their yields vary significantly depending on the sowing date and meteorological features of the year (Table 1). Thus, at the spring sowing date in 2006-2007, there was a generally favorable picture in terms of heat availability and rainfall, which resulted in a reduced weed infestation – 142-160 pcs/m². Weeds in the cenosis did not compete with Sudan grass, which had a favorable effect on its yield - 15.60-17.42 t/ha of green matter.

**Table 1.** Influence of sowing date and cover crop on crop infestation

| Cover crop       | Establishment year | Weeds for m² | Cover yield, herbage t/ha |
|------------------|--------------------|--------------|--------------------------|
|                  |                    | pieces          | g                         |                          |
| **Springsowingtime** |                    |               |                          |
| Sudan grass      | 2006               | 142           | 312                      | 15.60                    |
|                  | 2007               | 160           | 340                      | 17.42                    |
|                  | 2008               | 110           | 1840                     | 11.56                    |
|                  | average            | 137           | 830                      | 14.86                    |
| **Summersowingtime** |                    |               |                          |
| Sudan grass      | 2006               | 450           | 1125                     | 13.71                    |
|                  | 2007               | 398           | 795                      | 12.44                    |
| Sudan grass + rapeseed grass | 2008 | 298 | 1485 | 15.11 | |
|                  | average            | 382           | 1135                     | 13.75                    |
| Millet+rapeseedgrass | 2006 | 473 | 1182 | 16.10 | |
|                  | 2007               | 312           | 930                      | 11.11                    |
|                  | 2008               | 212           | 1230                     | 12.42                    |
|                  | average            | 332           | 1114                     | 13.21                    |
| **Late summer sowingtime** |        |               |                          |
| Rapeseedgrass    | 2006               | 112           | 235                      | 13.80                    |
The formula proposed by Willey and Rao [14] established a Competitive Ratio (CR) between weeds and the cover crop, by which one can judge the superiority and the ability to dominate one or the other component in the herbage.

It was established that at spring sowing in years with sufficient moisture (in 2006, the CR = 1.49 and in 2007, the CR = 1.41) weed species had the CR = 2.81-3.88 and Sudan grass had the CR = 0.65-0.72, which shows the competitive advantage of weed vegetation. In our opinion, the explanation lies in differences in species biology, namely in the ability of weed seeds to germinate at low soil temperatures and to develop during return frosts. Sudan grass has higher heat requirements during the sprouting period, hence its lower competitiveness.

In 2008, the HTC for the period from May to August was 0.84, which characterizes it as insufficiently wet. During and after sowing, there was a lack of moisture in the topsoil at high temperatures. Although the Sudan grass is a drought-tolerant crop, it sprouted unevenly and the weeds, species more adapted to unfavorable environmental conditions, took up empty space in the crops. With their relatively low numbers (110 pcs. /m²), their total mass was 1840 g, which is the highest value of all dates and years of sowing. However, the CR value of the weeds was 1.20 and that of Sudan grass 1.89, which indicates its greater competitive ability in the specific conditions of the year.

Weed infestation was the highest in the summer period of sowing and amounted in favorable years (2006, 2007) to HTC = 1.41 and 1.49 - 312-473 weeds per m² which in most cases corresponded to the number of bromegrass plants. Weed growth was promoted by warming of the top soil layer and high precipitation. The formation of large weed biomass - 1125-1182 g/m², and 795-930 g/m² respectively - was observed on both cover variants. CR was expectedly higher in weeds.

In the drier 2008, at the summer sowing date, the number of weeds was significantly lower, 212-298, but their mass was higher than in previous years, 1785-1830 g/m². However, after calculating the competitiveness coefficient, the dynamics of the spring sowing date in 2008 was repeated, when the CR value was higher for cover crops than for the weeds.

In the late summer sowing period, two pre-sowing cultivations significantly reduced weed infestation, with weed numbers ranging from 51-112 pcs. /m². Under these conditions, the cover crops produced a yield of 10.45-26.05 t/ha of the herbage.

The value of competitiveness at this sowing date was significantly higher for weeds than for cultivated species in all years. This is due to the late sowing date and the accumulation of biomass by the plants in conditions with insufficient air temperatures.

After harvesting the cover crops in phases according to the scheme of experiments, observations of growth and development of awnlessbromegrass were made on three time-steps which showed that the number of its plants sprouting per m² can vary significantly during the growing season depending on the sowing date, the cover crop and conditions of the year. Thus, in 2006-2008 the highest saving rate of awnlessbromegrass by the spring of the next year was noted at late-summer sowing under winter rye cover - 97% (table). It was somewhat lower when sown at the same period under cover of rape and its mixture with oats - 84-88%. Bromegrass standing density in spring was 294-346 pcs. /m² which was 72-79% higher than at the summer sowing date and 32% higher than at the spring sowing date.

Table 2. Preservation of bromegrass plants on average for three establishments, %

| Year       | CR 2006 | CR 2007 | CR 2008 | CR Average |
|------------|---------|---------|---------|------------|
| Oat+rapeseedgrass | 4,42    | 13,14   | 10,45   | 11,20      |
| Winter rye | 20,41   | 19,78   | 15,30   | 18,80      |
| Average    | 56      | 150     | 150     | 153        |

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With the late summer sowing date, the soil is fallow for a considerable time, allowing for weed control and moisture accumulation. This had a favorable effect on the bromegrass seedlings, the number of which amounted to 273–389 pcs/m² depending on the cover. Infestation was the lowest of all variants and amounted to 56–95 pcs/m². In addition, the choice of rape, oats and winter rye as a cover was correct as these crops are not strong competitors to awnless bromegrass for growth factors which is confirmed by data in table 3. Bromegrass plant height during sowing in late summer—autumn was 20.3–23 cm with root length up to 11.7 cm which was the maximum among all variants. The average number of shoots per plant -2 pcs, which, given the age of the grass, is a good indicator.

**Table 3. Biometric indices of awnless bromegrass in autumn, before going into winter, on average for 2006-2008**

| Cover crop | Number of shoots per plant, pcs | Plant height, cm | Root length, cm |
|------------|---------------------------------|------------------|-----------------|
| Sudan grass/spring | 2 | 16.8 | 9.4 |
| Sudan grass + rapeseed grass/summer | 1 | 11.2 | 7.1 |
| Millet + rapeseed grass/summer | 1 | 14.8 | 9.8 |
| Rapeseed grass/late summer | 2 | 20.9 | 9.4 |
| Oat + rapeseed grass/late summer | 2 | 23.0 | 11.7 |
| Winter rye/late summer | 2 | 20.3 | 11.0 |

In conditions of Siberia, it is recommended to sow bromegrass as a cover crop in spring, and it is traditionally suggested to use cereals (oats, barley) pure or mixed with legumes (vetch, peas) as a cover component [15]. Sudan grass is a drought-resistant crop with high potential of use, and thanks to its ability to form a strong herbage it actively oppresses bromegrass. At the expense of reserves of soil moisture in spring a fairly dense stand of bromegrass was formed - 464 pcs./m² which decreased to 336 during the growing season. Harvesting of the cover crop in the phase of hatching for green fodder allowed bromegrass plants to get stronger and prepare for winter.

According to the literature, it is recommended to sow bromegrass without a cover, reducing possible competition from the cover when soil moisture is scarce. In addition, it is possible to carry out 1-2 cultivations, which reduce the number of weeds. In our climatic conditions, the traditional July rains occur at this time, which is usually the time when grasses are sown.

During sowing in summer there was a significant increase in weeds (chicken millet, bittercane, pinewort), which numbered 338-382 plants or 1314 g/m². The precondition for this was high precipitation exceeding multi-year rates and compaction of the topsoil. Though weed retention rate was quite high at 76-88% the next year, in quantitative terms it was obviously insufficient - 73-98 plants/m². Weeds and cover crop significantly depressed bromegrass, which visually was underdeveloped and had yellowish leaves. This is confirmed by biometric data, where its height, number of shoots and root length are minimal compared with other variants.

The maximum dry matter yield of bromegrass was recorded at the late summer sowing date under the cover of oats with rape - 6.72-10.43 t/ha, which is 14-21% higher than at sowing at the same date under winter rye (the closest variant in terms of yield) (Table 4). In our opinion, the decisive factor
here was the fact that due to the late sowing date, the soil had been fallow before sowing. And since bromegrass is a cereal plant, its responsiveness to the level of mineral nutrition, namely nitrogen content, is quite high. In the natural environment, this is especially true in symbiosis with leguminous crops [16].

**Table 4.** Dry matter yield of bromegrass averaged over the years, t/ha

| Covercrop/sowingdate | Establishment 2006 (4-year data) | Establishment 2007 (3-year data) | Establishment 2008 (2-year data) |
|----------------------|---------------------------------|---------------------------------|---------------------------------|
|                      | 1 mowing | 2 mowing | Sum     | 1 mowing | 2 mowing | Sum     | 1 mowing | 2 mowing | Sum     |
| Sudan grass/spring   | 3.75      | 2.61      | 6.36    | 3.82      | 0.93      | 4.75    | 2.38      | 1.55      | 3.93    |
| Sudan grass+rapeseed grass/summer | -      | -      | -      | 4.86      | 2.88      | 7.74    | 2.78      | 1.17      | 3.95    |
| Millet+rapeseed grass/summer | -      | -      | -      | 4.95      | 1.97      | 6.92    | 3.70      | 1.17      | 4.87    |
| Rapeseed grass/ the end of summer | 4.63  | 3.80      | 8.43    | 4.59      | 2.73      | 7.32    | 2.75      | 1.70      | 4.45    |
| Oat + rapeseed grass/ the end of summer | 4.62  | 3.86      | 8.48    | 6.09      | 4.34      | 10.43   | 4.08      | 2.64      | 6.72    |
| Winter rye/ the end of summer | 4.45  | 2.65      | 7.10    | 6.15      | 2.91      | 9.06    | 3.65      | 1.66      | 5.31    |
| LSD05               | 1.50      | 1.03      | 1.92    | 0.61      | 1.14      | 1.43    | 0.72      | 0.55      | 0.94    |

The results of variance analysis of dry mass yields of bromegrass over the three plantings over time showed that the proportion of influence of meteorological conditions of the year, the cover crop and the interaction of these two factors, are reliable with a high probability (P<0.001).

With the prevalence of years with favorable growing seasons for bromegrass (3/1), the proportion of the influence of the year A factor on the yield was 65% and that of the cover crop factor B 20%.

When the ratio of favorable to unfavorable years was close to equal (3/2), the proportion of factor influence was equal (36% each). With an equal ratio of favorable to unfavorable development conditions (1/1), the influence of year conditions decreased and the value of the cover crop increased to 56%. Regarding the variability caused by the interaction of AB factors, it should be noted that for all plantings its values ranged from 8 to 16%.

The content of nutrients in the dry mass of bromegrass depended on the age of the grass and weather conditions. At a late sowing date, the following year the content of fodder units in the mass of bromegrass was lower than at an early sowing date. This is explained by insufficient development of plants and their failure to reach the physical state of ripeness. Later on, with the age of the herbage, all differences are levelled out. Nutritive value of dry mass of bromegrass was 0,52-0,81 fodder unit in the first cutting and 0,57-0,65 in the second one.

The exchange energy content varied widely between 7.2 and 10.5 mJ.

In terms of yield per hectare of nutrients for 3 years of grass use on this option was obtained: feed unit - 13.2 t, proc. prot. - 1.56 t, AE 179.2 GJ. If we compare these figures with the spring sowing date, they are 30, 49 and 29% higher, respectively.

When calculating the cost-effectiveness of grass cultivation, the 2019 prices were taken as a basis - the cost of hay is 1500 rubles/tonne, fuel is 45 rubles/kg, seeds: Sudan grass - 35, rapeseed grass - 35, millet - 20, oats - 10, rye - 8, bromegrass - 100 rubles/kg. After calculating the costs, it was found that 2913 rubles/ha were spent for sowing and harvesting perennial grasses.

It was established that sowing of awnlessbromegrass from the 10th to the 20th of July under the cover of a mixture of oats with rape, depending on the conditions of the year, gives a net profit of 7167-12732 rubles/ha. Sowing at the same time under the cover of winter rye reduces the net income by 29%; at the summer sowing date the income was lower by 31%.

**4. Conclusions**
1. Studies have shown that the maximum survival rate of bromegrass is achieved when sown from 10 to 20 July under a cover of rape, its mixture with oats or winter rye is 84-97%. This is explained by creation of favorable conditions for growth when the field is fallow before sowing and as a consequence weed control and accumulation of moisture in the soil. This is a powerful stimulus for development of bromegrass, especially in the initial stages. The average dry matter yield during the years of research was 4.45-10.43 t/ha, net income 3762-12732 rubles/ha.

2. The use of Sudan grass as a cover crop when sown from May 15 to 25 results in the loss of bromegrass from the herbage up to 49%, but due to the early harvesting of the cover crop, bromegrass has time to accumulate enough spare nutrients for a successful overwintering. The annual dry matter yield is 3.9-6.3 t/ha, with an average net income of 4606 rubles/ha.

3. When bromegrass is sown from June 10 to 20 under the cover of mixtures of bromegrass with rape or millet with rape, the grass is suppressed both by the cover crops and by the weeds, for which at this time the most favorable conditions for growth. However, after harvesting the cover crop, bromegrass forms a grass stand with a yield of 3.9-7.7 t/ha of dry matter, and the income from the sale of the crop is 2937-8637 rubles/ha.

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