Features of perennial forage agriculture in the North Caucasian foothills

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Abstract. The article presents the results of studies on the seeding time of perennial forage crops in the foothill area of North Ossetia-Alania. An agricultural method which is necessary is the pre-sowing treatment of seeds with natural agronomic ores in a ratio of 1:2 and simultaneous seed scarification. The studies revealed that the most optimal seeding time in terms of field germination and plant safety for harvesting for all the studied crops was the variant of the middle seeding time in the second ten-day period of May, when the soil temperature was warmed up to 12-14 °C. Also, when seeded late, the plantings of the studied crops significantly decreased in terms of leaf area—by 1.9 thousand m²/ha for burnet, by 1.2 thousand m²/ha for clover, by 1.5 thousand m²/ha for medicago, by 1.5 thousand m²/ha for sainfoin, by 1.5 thousand m²/ha for galega, by 0.8 thousand m²/ha for festulolium. Over four years, the average biochemical composition of perennial grasses of different seeding periods did not differ significantly in the content of forage units, digestible protein and metabolic energy. Thus, depending on the seeding time, fluctuations in the content of forage units were as follows: 2.21-2.24 t/ha for clover; 2.09-2.21 t/ha for medicago; 2.34-2.46 t/ha for sainfoin; 2.69-2.79 t/ha for galega; 2.27-2.41 t/ha for festulolium; 2.56-2.74 t/ha for burnet. The digestible protein content, respectively: 0.37-0.44 t/ha for clover; 0.51-0.55 t/ha for medicago; 0.49-0.54 t/ha for sainfoin; 0.43-0.57 t/ha for galega; 0.38-0.44 t/ha for festulolium; 0.57-0.64 t/ha for burnet. The output of metabolic energy was: 48.9-51.7 GJ t/ha for clover; 38.4-43.2 GJ t/ha for medicago; 39.3-42.4 GJ t/ha for sainfoin; 41.7-46.3 GJ t/ha for galega; 48.7-52.3 GJ t/ha for festulolium; 40.5-42.7 t/ha for burnet. Moreover, the crops of early and medium time of seeding had the highest values of biochemical composition.

1. Introduction
In conditions of deficiency of mineral and organic fertilizers, it becomes important to search for the ways to restore soil fertility and increase the agroecosystem performance based on rational use of natural resources and cultivation of crops that enrich the soil with nutrients. Such natural sources are perennial grasses, the number of which is reduced annually in the crop rotation system. In addition, a mixture of forage grasses is a valuable animal fodder [1-6].

However, the number of areas under grasses decreases annually, which does not provide the forage base with the necessary feeding and croplands with necessary nutrients. The lack of modern technologies for grass cultivation and seed stock do not ensure enough agricultural production [5, 7, 8]. Excessive use of croplands in the current modern farming system has led to decrease in their...
natural fertility, to development of a number of different types of undesirable processes occurring in the soil [6, 9, 10]. Among these processes, decrease in the total humus supply, excessive firming of soil, decrease in the amount of calcium, degradation, water and wind erosion, evaporation of the reflectivity of the soil, and other adverse factors are widespread. In addition, the modern farming systems have a particular practical difficulty which is the problem of the reproduction of organic matter in soils. One of the main sources of organic matter is green fertilizer which in most cases is based on grasses [11-14].

2. Research methods and objects
The main condition for growing high yields of perennial grasses is the proper determination of the optimal seeding time. The main agricultural method is pre-sowing seed treatment with natural agronomic ores. The republic has large reserves of zeolite-containing clays (irlite, alanite, tereklite, leskenite, beculite, etc.), which differ in chemical composition and in the reaction of the medium depending on the location. The average pH is 6-7. The lowest acidity is found in natural clay irlit 7, the pH of which is 3.8, and the maximum is found in clay beculite (in the range of 8.7–9.3). Alkaline clays were used on acid leached humus. Before sowing, the seeds were mixed with natural zeolite-containing clays in a ratio of 1:2, that is, at a sowing rate of 10 kg of seeds, 20 kg of agronomic ores. The experiments on seed preparation for sowing showed that, along with scarification, a positive effect is provided by the agronomic technique of mixing seeds with alanites, especially on sub-acid leached humus. Having sorption abilities, clay elements retain moisture in the seed bed and help increase seed germination. For the effectiveness of pre-sowing treatment, stimulants were tested on old-aged seeds with a shelf life of 6-19 years. When preliminary scarified seeds are sown together with alanite clay, the germination increased by 12-16%.

The seeding time is not only determined by soil temperature but also by its necessary moisture content. Seeding perennial grasses is optimal when the ploughed layer of soil contains about 20 mm of productive moisture [12, 15, 16].

The foothills of the North Caucasus is a zone of sufficient moisture; therefore, we did not face the task of providing the soil with moisture, however, it is necessary to know the optimal parameters of the soil temperature for different periods of seeds sowing [4, 16]. Therefore, when choosing the seeding time, 1st, 2nd and 3rd ten-day periods of May were selected.

The experiments were carried out on 6 crops: clover, medicago, sainfoin, galega, festulolium, and burnet. In our region, the technology of cultivating perennial grasses, and in particular the technology element (seeding time), has not been sufficiently developed, which results in a low realization of the forage crops potential. In our research, this was a decisive factor of studying the seeding time of perennial grasses of various species composition.

3. Field germination and plant safety
The studies revealed that the most optimal seeding time in terms of field germination and plant safety for harvesting for all the studied crops was the variant when the average seeding time was the first ten-day period of May, when the soil temperature is warmed up to 12-14 °C. When seeds were treated with local agronomic ores, germination ability increased and moisture remained, since natural zeolite-containing clays have low percentage of water loss (about 3%). So for the red clover crops, field germination varied within 60.9-63.8% depending on the period, and its safety varied within 84.2-85.3%, medicago field germination rate was 60.4-63.9%, safety index—80.9-82.4%, sainfoin field germination rate—61.8-67.1%, safety index—82.3 -83.5%, galega field germination rate—66.4-69.3%, safety index—83.2-84.7%, festulolium field germination rate—65.3-67.2%, safety index—84.3-87.6%, burnet field germination rate—60.7-63.0%, safety index—73.7-75.3%. Comparing with the control variant, all species of the studied grasses had a rather high germination and plant safety.
4. Grass wintering
It was also revealed that the winter hardness of the studied crops increases with the age of agrocenosis, except for clover in which, by the third year of life, winter hardness slightly decreases from 91.0% to 84.1% (Table 1).

Table 1. Percentage of wintering of perennial grasses depending on seeding time (average for 2015-2018).

| Soil temperature when seeding °C | Seeding time | 2nd year of usage | 3rd year of usage | 4th year of usage |
|----------------------------------|-------------|-------------------|-------------------|-------------------|
| 10-12                            | I/V         | 86.1              | 91.0              | 84.1              |
| 12-14                            | II/V        | 86.4              | 92.4              | 85.9              |
| 14-16                            | III/V       | 85.7              | 90.6              | 83.7              |
| Medicago                         |             |                   |                   |                   |
| 10-12                            | I/V         | 78.3              | 84.2              | 90.5              |
| 12-14                            | II/V        | 79.1              | 85.1              | 90.8              |
| 14-16                            | III/V       | 76.6              | 83.7              | 89.4              |
| Sainfoin                         |             |                   |                   |                   |
| 10-12                            | I/V         | 82.4              | 88.2              | 96.3              |
| 12-14                            | II/V        | 84.2              | 89.4              | 94.1              |
| 14-16                            | III/V       | 80.7              | 87.6              | 93.2              |
| Galega                           |             |                   |                   |                   |
| 10-12                            | I/V         | 80.2              | 87.4              | 92.7              |
| 12-14                            | II/V        | 82.7              | 90.2              | 93.0              |
| 14-16                            | III/V       | 79.9              | 85.6              | 90.2              |
| Festulolium                      |             |                   |                   |                   |
| 10-12                            | I/V         | 81.4              | 86.7              | 93.1              |
| 12-14                            | II/V        | 82.2              | 87.3              | 93.7              |
| 14-16                            | III/V       | 80.3              | 85.6              | 90.0              |
| Burnet                           |             |                   |                   |                   |
| 10-12                            | I/V         | 80.2              | 88.2              | 94.0              |
| 12-14                            | II/V        | 81.6              | 89.7              | 95.3              |
| 14-16                            | III/V       | 78.1              | 86.2              | 92.6              |

The highest percentage of successfully wintered plants was observed in the early and middle seeding periods; in case of the late seeding period, the winter hardness decreases for all studied crops.

5. Photosynthetic activity
The studies have found that in case of the middle period of seeding, the plants form a stronger assimilation surface compared to the ones seeded in the early and the late periods (Table 2).

During the study period, the burnet crops had the maximum leaf area (38.6 thousand m²/ha). The plantings of the studied crops significantly decreased in terms of leaf area when seeded in the late seeding period—by 1.9 thousand m²/ha for burnet, by 1.2 thousand m²/ha for clover, by 1.5 thousand m²/ha for medicago, by 1.5 thousand m²/ha for sainfoin, by 1.5 thousand m²/ha for galega, by 0.8 thousand m²/ha for festulolium.

Also, the plants of early and medium times of seeding, in terms of photosynthesis productivity, were characterised by the highest values, before the onset of flowering, after which this indicator decreased until the end of the growing season. The lowest percentage of pure photosynthetic efficiency was observed in crops of the late seeding time.
Table 2. Influence of seeding time on photosynthetic activity of perennial grasses (average for 2015-2018).

| Soil temperature when seeding °C | Seeding time | Leaf area, m²/ha | Photosynthetic potential, million m² × days/ha | Pure photosynthetic efficiency, g/m² × days | Yield, t/ha |
|---------------------------------|-------------|-----------------|-----------------------------------------------|---------------------------------------------|-------------|
|                                 |             |                 |                                               |                                             | Herbage     | Dry basis |
| 10-12                           | I/V         | 27.4            | 1.34                                          | 2.03                                        | 18.6        | 4.74       |
| 12-14                           | II/V        | 28.2            | 1.37                                          | 2.06                                        | 20.7        | 4.91       |
| 14-16                           | III/V       | 27.0            | 1.33                                          | 2.03                                        | 17.6        | 4.56       |
| 10-12                           | I/V         | 25.9            | 1.27                                          | 2.01                                        | 24.7        | 4.93       |
| 12-14                           | II/V        | 27.6            | 1.31                                          | 2.06                                        | 25.4        | 4.97       |
| 14-16                           | III/V       | 25.1            | 1.24                                          | 1.98                                        | 23.9        | 4.86       |
| 10-12                           | I/V         | 32.1            | 2.0                                           | 3.3                                         | 26.7        | 4.41       |
| 12-14                           | II/V        | 33.2            | 2.1                                           | 3.4                                         | 27.4        | 4.49       |
| 14-16                           | III/V       | 31.7            | 1.9                                           | 3.2                                         | 25.8        | 4.27       |
| 10-12                           | I/V         | 26.9            | 1.60                                          | 3.0                                         | 33.4        | 4.58       |
| 12-14                           | II/V        | 26.7            | 1.50                                          | 2.9                                         | 34.2        | 4.63       |
| 14-16                           | III/V       | 25.4            | 1.40                                          | 2.7                                         | 33.0        | 4.59       |
| 10-12                           | I/V         | 32.6            | 1.28                                          | 1.72                                        | 20.4        | 6.33       |
| 12-14                           | II/V        | 34.1            | 1.46                                          | 2.38                                        | 21.7        | 6.54       |
| 14-16                           | III/V       | 33.3            | 1.39                                          | 2.12                                        | 20.5        | 6.31       |
| 10-12                           | I/V         | 38.1            | 1.73                                          | 2.91                                        | 25.7        | 5.12       |
| 12-14                           | II/V        | 38.6            | 1.74                                          | 2.98                                        | 26.0        | 5.30       |
| 14-16                           | III/V       | 36.7            | 1.70                                          | 2.87                                        | 25.1        | 5.01       |

6. Grass efficiency

The analysis of yield data revealed that its maximum values are closely correlated with the temperature regime of the soil (table 3).

With an increase in soil temperature to 12-14 °C by the second seeding period, the maximum yield data were obtained for all studied crops, both herbage and dry basis. Over the years of research, the average increase in the herbage yield by the early seeding period for clover amounted to 9.0-8.5%, for medicago—9.4-9.7%, for sainfoin—9.4-9.7%, for galega—9.6-9%, 8%, for festulolium—9.4%, for burnet—9.6-9.9%.

A similar pattern is observed in the dry basis yield, which was closely correlated with the herbage. Over four years, the average biochemical composition of perennial grasses of different seeding periods did not differ significantly in the content of forage units, digestible protein and metabolic energy. Thus, depending on the seeding time, fluctuations in the content of forage units were as follows: 2.21-2.24 t/ha for clover; 2.09-2.21 t/ha for medicago; 2.34-2.46 t/ha for sainfoin; 2.69-2.79 t/ha for galega; 2.27-2.41 t/ha for festulolium; 2.56-2.74 t/ha for burnet. The digestible protein content, respectively: 0.37-0.44 t/ha for clover; 0.51-0.55 t/ha for medicago; 0.49-0.54 t/ha for sainfoin; 0.43-0.57 t/ha for galega; 0.38-0.44 t/ha for festulolium; 0.57-0.64 t/ha for burnet. The output of metabolic energy was: 48.9-51.7 GJ t/ha for clover; 38.4-43.2 GJ t/ha for medicago; 39.3-42.4 GJ t/ha for sainfoin; 41.7-46.3 GJ t/ha for galega; 48.7-52.3 GJ t/ha for festulolium; 40.5-42.7 t/ha for burnet.
Moreover, the crops of early and medium time of seeding had the highest values of biochemical composition.

**Table 3.** Influence of seeding time on the efficiency of perennial grasses (average for 2015-2018).

| Soil temperature when seeding °C | Seeding time | Forage units, t/ha | Digestible protein, t/ha | Metabolic energy GJ, t/ha |
|----------------------------------|--------------|--------------------|--------------------------|--------------------------|
| 10-12                            | I/V          | 2.39               | 0.41                     | 50.4                     |
| 12-14                            | II/V         | 2.44               | 0.44                     | 51.7                     |
| 14-16                            | III/V        | 2.21               | 0.37                     | 48.9                     |
| 10-12                            | I/V          | 2.17               | 0.53                     | 39.9                     |
| 12-14                            | II/V         | 2.21               | 0.55                     | 43.2                     |
| 14-16                            | III/V        | 2.09               | 0.51                     | 38.4                     |
| 10-12                            | I/V          | 2.43               | 0.52                     | 41.0                     |
| 12-14                            | II/V         | 2.46               | 0.54                     | 42.4                     |
| 14-16                            | III/V        | 2.34               | 0.49                     | 38.4                     |
| 10-12                            | I/V          | 2.71               | 0.55                     | 44.6                     |
| 12-14                            | II/V         | 2.79               | 0.57                     | 46.3                     |
| 14-16                            | III/V        | 2.69               | 0.43                     | 41.7                     |
| 10-12                            | I/V          | 2.34               | 0.41                     | 50.9                     |
| 12-14                            | II/V         | 2.41               | 0.44                     | 52.3                     |
| 14-16                            | III/V        | 2.27               | 0.38                     | 48.7                     |
| 10-12                            | I/V          | 2.70               | 0.61                     | 42.0                     |
| 12-14                            | II/V         | 2.74               | 0.64                     | 42.7                     |
| 14-16                            | III/V        | 2.56               | 0.57                     | 40.5                     |

7. **Conclusion**

Based on the foregoing, we can state that the most favorable seeding season for perennial grasses in the foothill zone of North Ossetia-Alania is seeding in the first and second ten-day periods of May, when the soil warms up to 10-12 °C in the early seeding time and 12-14 °C in the middle seeding time. In case of sowing seeds with zeolite-containing clays along with preliminary seeds scarification, the germination ability of seeds increases by 12-16%. Due to the preparation of seeds for sowing, their germinating ability, winter hardiness of plants, photosynthetic efficiency, yield and quality are increased. Studying the diversity of perennial grasses under crop rotation will preserve not only soil fertility, but also provide livestock with feed.

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