Using natural fertilizers for increasing red clover seed productivity

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Abstract. Considerable environmental significance of red clover (Trifolium pratense L.), a forage and medicinal herb, which increases soil productivity and serves as melliferous plant, provides the grounds for using its seeds for further cultivation. Resource-saving technologies of its cultivation have to be justified. To achieve the objective, we used natural fertilizers of local origin. They included Karmadon boron-containing mineral water and Alanit zeolite clay; besides, we had to determine the right preceding crop in crop rotation link in order to achieve maximum possible seed harvest. Seed grass was planted in mountain and foothill conditions after different preceding crops. It was established that the best preceding crops for red clover are winter cereals that enrich areas with a considerable amount of boron and molybdenum. We determined optimal doses for foliar feeding with mineral water and pre-sowing seed treatment. Clover plantings were placed in wide rows after the first forage mowing to ensure better flower pollination. On the slopes, we placed medic plantings with extensive root system in the row spacing of third-year clover by so decreasing erosion processes. The use of natural fertilizers containing macro- and microelements contributed to increasing seed productivity by 17-25%. We established the advantage of wide-row sowing with undersowing medic in the row spacing for decreasing erosion processes in mountain conditions.

1. Introduction

Red clover is a primary source of hay and green forage with a high content of protein, mineral substances and vitamins in mountain and foothill districts of North Ossetia-Alania. Clover cultivation in the conditions of the region requires seeds the lack of which is a deterrent factor preventing further extension of the plantings. Besides, clover plays an important role in soil improvement, as it increases soil fertility. Clover is the best preceding crop for all the agricultural crops. A good grass stand leaves from 50 to 60 centners/ha of root and afterharvesting residues containing more than 100 kg of fixed nitrogen. Clover is widely used for developing cultivated pastures, improving perpetual meadows, preparing grass pellets, etc [1, 2].

Due to the lack of seeds, expensive seeds of unknown origin are imported every year from other regions of the country with different climate conditions. As a rule, imported seeds of biotypes not adapted to the conditions of our republic produce low harvest [3, 4].
In this connection, it is important to cultivate clover using region-specific varieties. The reason for low clover seed productivity in farming units of the republic (0.5-0.8 centners/ha) is insufficient development level of agricultural infrastructure [5, 6].

In Fore-Caucasus clover is considered a hydrophilous plant. It is cultivated for forage and seeds in forest steppe and forest skirts, on mountain and foothill areas. The climate is warm and quite wet in the region; annual precipitation amounts to 600-670 mm [7]. Clover fresh yield is higher and more stable than that of medic. However, it is not always possible to receive clover seeds due to frequent rains in the period of florescence and harvesting.

Pollination is one of the key factors of abundant harvest. The success of this process is determined by such conditions as sunny weather and optimal temperatures (22-28°C). Dry weather allows for good quality of harvesting.

Clover seeds growth requires the sum of positive temperatures to be at least 1300-1800°. Such numbers prevail on the whole territory of the republic, which means that all its areas are favorable for seed planting. However, the precipitation is abundant in the period of florescence (over 200 mm), which makes pollen gluey; bees do not pollinize flowers and, as a result, seed setting rate is low [8].

Results of production experiments prove the fact that seed productivity reaches maximum level when hydrothermal coefficient remains within the range of 1.52-3.12 (i.e. when the sum of positive temperatures higher than 10°C is 1428-1648 and total precipitation is 250-445 mm for the period of vegetation) [9].

Clover is especially demanding when it comes to soil surface. This is the reason why soil preparation must include the following aspects: removing weeds from the whole land plot, accumulation and conservation of moisture in the soil, accumulation of nutrients in easily consumable form, levelling the surface and creation of crumbly structure of the upper level and solid structure of seed covering level. It is achieved by timely field preparation after gathering preceding crops.

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In mountain areas, optimal hydrothermal coefficient (HTC) for heights from 700 to 1000 above sea level is 4.6-8.16. Terms of sowing on foothills were determined depending on HTC value. The lower is HTC value, the earlier sowing must be started in the period from 5-10 April to 20-25 April [10].

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Levelling field surface is an essential procedure, since it improves the quality of planting as well as harvesting.

Soil compaction is required before sowing. Sowing without compaction is a serious violation of agricultural technology. Compaction destroys large crumbs and thickens upper soil level, which allows for uniform seed covering, increases moisture flow to the upper level and results in even sprouts. Pre-sowing soil compaction increases field germination capacity by 10%-12%.

Segmented ridged rollers for heavy soils compacting prevent soil crusting.

On seed grass, fertilizers reduce grass lodging, ensure proper formation of reproductive plant organs, create optimal conditions for activity of pollinators, stimulate formation of high-quality pollen, ripening and even maturation of seeds.

Optimal soil pH must be ensured at the land plots designated for seed planting. Soil can be limed in winter or in spring before sowing. Fertilization program consists of primary and pre-sowing fertilization, as well as introduction of nutrient supplements with macro- and microelements during the whole period.
of growth and development. Primary fertilizer is introduced to the soil before tillage and during pre-sowing treatment, taking into account peculiarities and demands associated with plant nutrition and soil composition.

Results of studies and best practices in our country and abroad prove that the best doses of phosphorus are 200 kg/ha; as for potassium, the best doses are 100-240 kg/ha. This amount of fertilizers helps to increase clover seed productivity by the second year. Phosphate-potassium fertilizers can be introduced to the soil before sowing as well as in the form of nutrient supplements for the second and subsequent years of life, in the spring and after the first mowing of the green forage mass until April 20-25. Micronutrient fertilizers, especially the ones containing boron and molybdenum, contribute to sustainable clover seed harvest production.

Boron participates in carbohydrate metabolism, influences development of reproductive plant organs and seed growth. Molybdenum improves development of root nodule bacteria and increases their nitrogen-fixing capacity.

Micronutrient fertilizers for clover can be introduced to the soil, used for pre-sowing seed treatment and added to nutrient supplements during vegetation period. Boron fertilizer must be used if mobile boron content in soil is less than 0.4-0.5 mg/kg. Molybdenum fertilizers are used if mobile molybdenum content in soil is 0.2-0.3 mg/kg [6, 11].

Common ways for forage legumes cultivation include introducing microelement supplements to grass stand. However, such method is used in the second year of life and after seed harvesting. There is an extinction of plants. This process is especially intense at foothill areas [3, 6, 12, 13].

Boron fertilizers are not always available for purchase, so in our research we used boron-containing mineral water of local origin. In particular, Karmadon contains mineral substances and microelements necessary to restore soil fertility.

2. Conditions and methods
The experiments were conducted in two contrasting environmental conditions. Soil of the foothill area is chernozem-type, leached and typical, while mountain area soil is mountain meadow-type chernozem leached with a humus content of 6-7% and pH of 5.0-6.5.

In mountain areas, optimal hydrothermal coefficient (HTC) for heights from 700 to 1000 above sea level is 4.6-8.16. Terms of sowing on foothills were determined depending on HTC value. The lower is HTC value, the earlier sowing must be started in the period from 5-10 April to 20-25 April.

Boron-containing mineral water of local origin was used as stimulant before sowing and after mowing.

Chemical composition of Karmadon mineral water is the following (mg/kg): Anions: Bicarbonates – 400-800. Sulphates – over 25. Chlorine –1000-1800. Cations: Calcium – over 100. Magnesium – over 25. Sodium, potassium – 700-1300. Specific component: boric acid – 80-200. This water was used to saturate local zeolite-containing clays to increase nitrogen-fixing capacity of two red clover varieties (Vladikavkaz and Darial) cultivated for the purpose of receiving seeds. Before sowing, seeds were covered in Alanit zeolite-containing clay of local origin with a weak alkaline reaction (pH 8.3) to increase nitrogen-fixing capacity. Alanit modified by boron-containing water in the amount of 12 kg per hectare norm of seeds created favorable conditions for plant growth and development.

Sowing method is broadcasting with oat as cover crop. In the next year broadcasted plantings were transformed into wide rows using cultivator.

Applied at the stage of flower bud formation, foliar feeding with boron-containing mineral water in the amount of 50, 100, 150 and 200 litres per 1 ha increased the amount of nectar and sugar content in nectar.

3. Research results
Boron-containing mineral water improved the development of root system and nitrogen fixation on it, by this improving development of plants themselves and formation of their reproductive organs. At the
same time general seed productivity increased by 17.4-25.0%. The most effective feeding dose for plantings is 100 litres per 1 ha (table 1).

The following data in the table 1 prove that high content of boron in the mineral water increases nectar amount in clover flowers and sugar content in it, which increases seed productivity.

| Experimental variations          | Amount of nectar in flower (mg) | Content of sugar in nectar (%) | Seed productivity (g/1 m²) | Proportion to the control variation (%) |
|---------------------------------|---------------------------------|-------------------------------|---------------------------|----------------------------------------|
| 1. Control (no nutrient supplements used) | 0.19                            | 18.9                          | 17.2                      | 100.0                                  |
| 1. Karmadon mineral water 50 l  | 0.22                            | 20.7                          | 21.0                      | 122.0                                  |
| 2. Karmadon 100 l               | 0.20                            | 22.4                          | 21.5                      | 125.0                                  |
| 3. Karmadon 150 l               | 0.23                            | 22.9                          | 20.2                      | 117.4                                  |
| 4. Karmadon 200 l               | 0.25                            | 23.5                          | 20.8                      | 120.9                                  |

As a rule, the first mowing of clover is aimed at receiving green fodder; the second one is aimed at receiving seeds. Seed plot was located at the area after winter wheat harvesting, as this cereal leaves considerable amount of boron and molybdenum in the soil, which are necessary elements for growth of clover seeds and development of nodule bacteria fixing nitrogen from the air. Wheat was harvested in the period from 5 to 10 July. After harvesting, stubble was ploughed down to the depth of 20-25 cm. After 1.5-2 months, clover was sown in the amount of 6-8 kg/ha. Such amount of seeds was sowed in wide rows after preceding winter cereal. We studied the possibilities of increasing clover seed amount after different preceding crops (cereals, potato and others) in crop rotation using cereal straw ash containing boron and molybdenum as nutrient supplement and seed treatment. To decrease erosion processes in mountain areas, we sowed two legumes (clover and medic). To be noted that medic was sown after clover seed harvesting, by undersowing it between the rows with further seed treatment with Alanit saturated with boron-containing mineral water in the proportion 1:0.5, i.e. 3 litres of mineral water per 6 kg/ha (seeding rate per hectare).

As a result of feeding, sugar content in nectar increased up to 23.5 mg and amount of nectar in flowers increased up to 0.25 mg. General seed productivity amounted to over 20 g/1m², which exceeded the control variation by 17-25%.

Clover seeds can be received after the first and the second mowing. However, the major part of the experimental data shows the benefits of seed harvesting after the second mowing. As a rule, seed harvest received after the second mowing is higher as compared to the first mowing [11,12].

Key factor ensuring high seed productivity after the second mowing is timely first mowing: no later than the phase of flower bud formation, which is a beginning of flowering.

Theoretical and practical studies in the conditions of North Ossetia-Alania have proven that higher seed harvest is received after the second mowing, as compared to the first mowing. This is explained by the fact that at the time of the second mowing, clover flowering occurs in the period of mass wild pollinator insect emergence and better activity of melliferous domestic bees. Moreover, seed grass stand is less likely to lie down. We could observe a more even flowering distribution and development of heads less infested by clover apionidae. Seeds received after the second mowing are cleaner, as the majority of weeds were removed during the first mowing.

Results of the experiments demonstrate that clover productivity is higher in the second year of life rather than in the third one; harvest received during the first mowing is a bit lower than during the second one (table 2). As a result of the first mowing, we received 1.07 centners/ha of Darial seeds, while during
the second mowing the harvest was higher by 0.5 centners/ha. As for Vladikavkaz clover variety, this indicator also exceeded the first mowing results by 0.37 centners/ha. In the third year of life, these indicators confirmed the pattern of the second year, where the seed productivity was higher by 0.3 centners/ha for the first variety and by 0.49 centners/ha for the second one.

**Table 2.** Seed productivity of red clover varieties for different mowings in different harvesting years.

| Variety  | Seed productivity (centners/ha) |  
|----------|---------------------------------|---
|          | First harvesting year (2nd year of life) | Second harvesting year (3rd year of life) |
|          | 1st mowing | 2nd mowing | 1st mowing | 2nd mowing |
| Vladikavkaz | 1.32 | 1.69 | 1.13 | 1.44 |
| Darial | 1.07 | 1.57 | 1.04 | 1.53 |

Considering high content of boron and molybdenum microelements after winter wheat harvesting, seed clover grass was planted with preceding cereal crop [12].

Stubble is ploughed in 5-7 days after winter cereals harvesting. Cereal straw contains 8.5 mg/kg of boron, 60 mg/kg of manganese, 0.33 mg/kg of molybdenum, 0.37 mg/kg of cobalt and 3.0 mg/kg of copper.

This amount is considerably lower than that of intertilled crops. Cereal crops take very small amount of microelements from the soil, leaving major part of them unused. Microelement content in the soil, including boron content, increases from 4 to 12 mg/kg per 1 kg of soil due to clover planting, as compared to preceding intertilled crops.

After intertilled crops, such as potato and beetroot, boron amount considerably decreases in soil, as these crops take 3-4 times more microelements from the soil, as compared to cereal crops.

Ploughing the soil with stubble, i.e. straw remains, 5-7 days after grain harvesting, when they start decomposing, ensures accumulation of microelements in soil.

Cultivators are periodically used for weed control to a depth no more than 8-10 cm.

Clover seed grass will provide succeeding potato, beetroot and other intertilled crop plantings with necessary elements, as it serves as a good preceding crop.

Grass crops do not lie down. The number of flower heads on each plant increases.

In comparison with the previously used technology, seed productivity increases by 1 centner/ha, which is a considerable increase in monetary terms. Table 3 demonstrates data on clover seed productivity with preceding potato and winter wheat.

It follows from the data provided in table 3 that the maximum seed productivity was achieved by sowing seed grass after winter cereal crops with pre-sowing treatment of seeds with ash containing sufficient amounts of boron and molybdenum.

Clover seed productivity depends to a great extent on grass stand thickness, which, in its turn, depends on seeding rate and planting pattern (row, wide row or strip).

It was established by FWRC FPA that there should be 40-80 plants with 250-360 simultaneously developing offshoots and 700-800 inflorescences in order to achieve maximum possible clover seed productivity per 1 m. This is achieved by wide-row planting method with sowing rate of 4-6 kg/ha.

The studies proved that wide-row planting method allows to receive 3.35 centners/ha of seeds, which is 0.8 centners/ha higher than for broadcasting method. However, wide-row sowing results in insufficient green forage mass harvest, while broadcasted plantings lie down, which decreases seed productivity.

It was established that combination of broadcasting and wide-row methods ensures increase in fodder and seed productivity per square unit. It is achieved in the following way: clover is sowed with oat as cover crop, sowing rate: 14-15 kg/ha. Full-fledged green forage mass harvest is received after the first mowing. After harvesting, wide rows with 45 cm of row spacing are formed with the common KRN-2.8 cultivator. With such planting method, seed productivity amounted to 1.75 centners/ha, which is 0.45 centners/ha higher than with common wide row planting. Increased seed productivity with this planting
method is explained by root remains between the rows which increase soil fertility. Such method decreases the amount of mechanical and chemical treatments, which has a positive influence on the environment. As compared to the wide-row planting, this agricultural method decreases amount of weeds, which increases seed productivity.

Table 3. Clover seed productivity depending on introduction of micronutrient fertilizers.

| Variations                                                                 | Seed productivity (centners/ha) | Increase in seed productivity (%) | Content in soil (mg/kg) |
|---------------------------------------------------------------------------|---------------------------------|----------------------------------|-------------------------|
| **Control**, Clover sowing with preceding potato, no micronutrient fertilizers introduced | 0.8                             | -                                | 3.6                     |
| Clover sowing with preceding potato, introduction of boron and molybdenum during flower bud formation in recommended doses | 1.8                             | 225                              | 7.1                     |
| Clover sowing with preceding winter wheat, no micronutrient fertilizers introduced | 2.2                             | 250                              | 8.8                     |
| Clover sowing with preceding winter wheat, no micronutrient fertilizers introduced, seeds treated with ash before sowing | 2.8                             | 350                              | 11.6                    |

Production experiments have proven that broadcasted plantings contained from 265 to 300 plants per 1 square metre. After transforming broadcasted plantings into wide rows with the KRN-3.6 cultivator and harrowing with the BP-8 aggregate, the amount of plants decreased to 110-130 per 1 square metre. Seed productivity on the rowed area amounted to 2.2 centners/ha, which is 0.5 centners/ha higher than for broadcasted plantings.

Today there is a vital problem associated with creation of seed grass, especially in mountain conditions, where grass is sowed on degraded mountain meadows for restoration of soil fertility. Due to their extensive root system, perennial grasses control erosion processes at foothill areas.

Common ways of forage legumes cultivation include introducing microelement supplements to grass stand. As a rule, such method is used in the second year of life and after seed harvesting. There is an extinction of plants. This process is especially intense at foothill areas.

To improve and preserve grass stand, two legumes are sowed (clover and medic). The legumes sowed together suppress each other. This process is especially well-marked in the second year of life. In the first year of life, these grasses are still underdeveloped, therefore erosion processes are observed.

In order to decrease erosion processes on foothill areas and receive maximum amount of seeds, clover was sown by broadcasting method with preceding winter wheat or winter barley in the first year; wide rows of grass plantings were formed after the first mowing of the second year of life and medic was interplanted at decreased seeding rate in the row spacing after harvesting. It must be noted that before planting, seeds were mixed with Alanit zeolite-containing clay saturated with boron-containing mineral water in the proportion 1:0.5.

Due to the fact that winter wheat and winter barley leave unused microelements, such as boron, molybdenum, cobalt, copper, manganese in the soil, they were chosen as preceding crops for forage legumes.

Microelements increase chlorophyll content in leaves, improve assimilating activity of the whole plant and contribute to photosynthetic processes. They have positive influence on development of seeds.
and their sowing qualities. Micronutrient fertilizers increase resistance of plants to different diseases and unfavorable environmental conditions (soil and air drought, excessive water saturation, high and low temperatures).

Clover and medic, as forage legumes, require large amounts of microelements. For this reason, preceding cereal crops allow to reduce costs of micronutrient fertilizers for forage legumes and increase their forage and seed productivity.

Wide-row planting shall be taken into account when preparing land plot, as it is important for active pollination by bees. Clover was sowed by broadcasting method to decrease the amount of weeds. In the next year, during flower bud formation phase, high-quality fodder was received after the first mowing. After the mowing, wide rows were formed by cultivator with space rowing of 60 cm, where medic was planted with sowing rate of 4 kg/ha. Such decreased sowing rate is crucial for better grass lighting, formation of reproductive plant organs and activity of pollinator bees. In the year of medic sowing, additional fodder is received at the end of vegetation phase. The next year (third year of clover life), the first forage legume extincts and leaves medic seed grass stand which is harvested during the first mowing. Medic grass stand develops extensive root system, which allows to receive green fodder mass and seeds during the next 6-8 years and increase soil fertility due to nitrogen-fixing capacity of forage legumes.

Considering the fact that favorable soil for clover plantings development is slightly acidic (pH 5-6), while medic requires neutral soil (pH 7-7.5), before planting the second crop, seeds were mixed with Alanit zeolite-containing clay saturated with boron-containing mineral water. Alanit contains 30-35% of calcium which reduces soil acidity. Mixing Alanit (50-60 kg/ha) with boron-containing water (30-40 ml/ha) increases the effect zeolite-containing clay has on reducing soil solution acidity.

The selected parameters are explained by the activity of Alanit with calcium content which reduces the acidity in the seedbed.

4. Conclusion
Pre-sowing treatment of seeds with boron-containing mineral water mixed with Alanit zeolite-containing clay of local origin increases productivity by 17–25%. Natural fertilizers increase nitrogen fixation of the cultivated plants, improve pollen quality and seed productivity.

Seed productivity is higher if the harvest is received from the second mowing and if the plants are fed with boron-containing mineral water during the first mowing. Such method increases seed productivity from the second mowing by 0.37-0.5 centners/ha.

The best preceding crops for forage legumes are winter cereals, as they leave sufficient amount of microelements in the soil which are necessary for full development of seed grass and formation of reproductive plant organs.

On foothill areas, the clover must be sowed by broadcasting method with oat as cover crop. After the first mowing, wide row plantings must be formed. In the third year of life, medic must be planted in row spacing, as it reduces erosion processes due to extensive root system.

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