Effectiveness of grassland crop rotation in the submontane area of the Republic of North Ossetia Alania

A A Abaev, D M Mamiev*, A A Tedeeva and V V Tedeeva

North Caucasus scientific research institute of mountain and submontane agriculture – branch of Federal Government Budgetary Science Institution of Federal centre «Vladikavkaz scientific center of the Russian Academy of Sciences», Mikhaylovskoye, The Republic of North Ossetia Alania

* E-mail: d.mamiev@mail.ru

Abstract. In conditions of the submontane zone of The Republic of North Ossetia Alania the investigated cultures of grassland crop rotation made positive effect on structurally-aggregate properties of soil, water stability of soil aggregates, and also on fruitfulness and energetic potential of cultivated crops. The most favorable impact on soil structure was made by clover and winter wheat, which are having more lengthy periods of vegetation, well developed root system, ensuring the better protection of soil in autumn and spring from the destructive effect of atmospheric precipitation. Intertilled cultures had low evaluation in this context. The capacity for structure formation is more weakly expressed in potatoes. In result of research it was revealed that the soil under study has good structural condition because it contains from 52.1 to 55.8% of water-stable aggregates. It was established that the weight by volume kept changing in all cultures of crop rotation. By the end of vegetation, the tendency of increasing weight by volume has been observed practically in all variants. In general, the average soil density under all cultures has been optimal during the whole period of research. The maximum output of feed units was marked among the following options: oat + clover – 9.83 t/ha, clover – 9.49 t/ha, corn – 9.49 t/ha. The more quantity of digested protein was contained in the crop of clover, for the rest of the cultures the index was approximately at the same level. The grass rotation where the pickup of feed units and digested protein was credibly exceeding the indices of intertilled rotation, was the more fruitful (7.96 t/ha – rotation grass and 6.33 t/ha – intertilled rotation).

1. Introduction
The further improvement in structure of crop acreage and farming rotation represents the important reserve of agriculture stabilization, increase of crop productivity and gross yield of grains, feeds and technical crops [1].

Crop rotations remain the key element of modern agriculture systems and solve the full range of tasks on rational usage of land, soil fertility recovery and protecting it from erosion, protection of environment and all agrarian landscape [2,3].

Current conditions of farm production don't allow to conduct full range of practices in soil fertility recovery to the full extent [4,5].

In crop rotation system of new generation there are stipulated the organizing, realization of economically and ecologically safe, effective means of treating the soil, forming the integrated protection of plants from pests, diseases and weeds, rational usage of organic and mineral amendments,
and even higher grows the necessity of switching them to the biologized and energy saving agriculture [6,7].

Crop rotation is an essential condition of correct management of agriculture. This is the most important agrotechnical and organizational/economic tool in farming [8,9].

In modern conditions the high effectiveness of crop rotations doesn’t arise any doubt; doing agriculture without crop rotation – isn’t possible.

2. Research methods
Research took place in the forest-steppe zone of The Republic of North Ossetia Alania. Soils of the test area are represented by leached chernozems on pebble-bed, they are characterized by high content of gross and available resources of nitrogen and phosphorus. By content of mobile potassium they are medium filled in comparison to other soils. Plow layer contains from 3.3% to 4.7% of humus. Reaction of soil solution in upper layers is neutral. Mean annual precipitation is up to 748 mm. Its seasonal dynamics gradually increases from winter to summer, reaching the maximum in June (143 mm). Later on, fallout of precipitation decreases, coming to the minimum in December – February (20-27 mm.). Relative air humidity in the area, during vegetation period, approaches around 74%.

Trial establishment, phenological observations, statistical treatment of the data received, were carried out according to the common methods, set out in the learning and teaching manual of E D Adiniyaev, A A Abaeva, N L Adaeva (2013) [10].

3. Results and interpretation
Soil structure – is the important characteristic of the physical condition of fertile soil. It defines the favourable built structure of a plow layer of soil, its water, physico-mechanical and technological properties. It’s proved that the structure of soil changes depending on the type of cultivated agricultural crop. Modification in proportion of the different soil fractions was observed in dynamics, both under cultures and soil layers. It’s deemed that, in average, during 3 years (table 1) under different cultures the cloddy structure (in beginning of vegetation) varied from 13,46 (winter wheat) to 49.56 % (corn), macro-structure – from 48.53 to 81.88 %, aggregates of less than 0.25 mm – from 1.88 to 8.01 %. Under corn (in beginning of vegetation) the cloddy fraction was 49.56 %, but by the end of vegetation this index reduced in 25.01 %; the similar situation was observed under potatoes as well. But under clover and winter wheat the reverse pattern was noticed: in the beginning of vegetation, the cloddy fraction amounted 15.32 % and 13.46 % respectively, and by the end of vegetation increased up to 24.09 % and 28.69 % respectively (table 1).

Table 1. Structural composition of soils in test area, average between 2018-2020 years, forest-steppe zone in the Republic of North Ossetia Alania, %.

| Variant          | Beginning of vegetation | End of vegetation | Coefficient of soil pedality |
|------------------|-------------------------|-------------------|-----------------------------|
|                  | >10 mm  | 10-0.25 mm | <0.25 mm | >10 mm  | 10-0.25 mm | <0.25 mm |                     |
| Oat + clover     | 25.13   | 67.89     | 6.98    | 24.18   | 72.19     | 3.63     | 2.59               |
| Clover           | 15.32   | 81.88     | 2.80    | 24.09   | 72.04     | 3.87     | 2.57               |
| Winter wheat     | 13.46   | 78.53     | 8.01    | 28.69   | 70.22     | 1.09     | 2.35               |
| Potatoes         | 27.17   | 68.42     | 4.41    | 25.86   | 70.14     | 4.00     | 2.34               |
| Corn             | 49.56   | 48.53     | 1.88    | 25.01   | 69.28     | 5.71     | 2.25               |

By the end of vegetation the proportion of silt fraction under winter wheat (the culture of broadcast seeding) reduced from 8.01 to 1.09 % and was the lowest one in the test. Under the cultures: for oat + clover and clover this index was equal to 3.63 and 3.87 % respectively (by the end of vegetation), but in the beginning – 6.98 and 2.80 %. Under potatoes, the proportion of silt fraction reduced from 4.41 % (beginning of vegetation) to 4.00 % (end of vegetation), and under corn this index kept increasing: from
1.88 to 5.71 %. Coefficient of soil pedality was changing within the range: 2.25 % (corn) and 2.59 % (oat + clover).

It was discovered that under the culture of broadcast seeding (winter wheat) the fractions 10-7, 7-5, 5-3, 3-2, 2-1 mm predominated, and they were increasing by the end of vegetation, and in row-crop planting (potato, corn) the fractions 2-1, 1-0.5, 0.5-0.25 mm prevailed, which were increasing also by the end of vegetation, especially in upper layer of soil (0-10 cm). It’s worth noting that, in case with intertilled cultures, at destruction of cloddy structure (0-10 cm) the aggregates of fraction 2-1 and less than 0.25 were increasing, but with the increase of megastructure proportion those fractions reduced.

It’s proved that the most favorable effect on structure was made by clover and winter wheat which are characterized by more prolonged vegetation period, well developed root system, by the best protection of soil in autumn and spring from the destructive effect of atmospheric precipitations and meltwaters and by the lesser intensity of treatment in vegetation period. Intertilled cultures had low evaluation thereof. The capacity for structure formation is specifically weakly expressed in potatoes, after which very less quantity of roots remains in the soil. Besides, while taking the crop, the soil is undergoing strong physical impact, the destruction of soil aggregates takes place, especially in high or too low soil moisture.

In crop rotation the impact of perennial grasses on water stability of structural aggregates, which were characterized by higher resistance to soil destruction due to its better humus content, was clearly defined. In result of research it has been established that the soil under study has good structural condition, because it contains from 52.1 to 55.8 % of water-stable aggregates.

It’s known that the soil weight by volume gives approximate representation about soil consistency, degree of providing plants with life factors – food, water, air. Deviation in density of soil consistency from optimum upwards or downwards worsens the conditions of plant’s life, reduces crop productivity. Density of soil consistency depends on mechanical soil content, humus content, texture and soil pedality.

It’s been established that the weight by volume was changing among all cultures of crop rotation depending on the period and depth of sampling. By the end of vegetation practically in all variants the tendency of increasing weight by volume was observed. In general, average soil density under all cultures was optimal during the entire research period. Thus, in beginning of vegetation the weight by volume reached up to 0.96 g/cm³ in average in the space of two years for oat + clover option (averagely in soil layer 0-30 cm), during the phase of intensive growth – 1.13 g/cm³, and in the end of vegetation – 1.21 g/cm³. Such tendency is traced in all cultures of crop rotation.

It’s a known fact that the important physical index of soil fruitfulness is the structure of the plow layer.

It was discovered that the maximum increase of hard phase proportion of soil during vegetation was noticed in winter wheat and corn, and this is explained by change in density of consistency. The highest indices of general porosity in the beginning of vegetation were discovered under the following cultures: oat + clover (57.5 %), clover (57.6 %) and potatoes (58.8 %), and by the end of vegetation - under clover (57.1 %) and potatoes (59.6 %). In crops of perennial grasses hard phase in the beginning of vegetation was at the level of 42.4-42.5 %, and by the end of vegetation it was varying in the range of 42.9-43.5 %.

The indice of capillary porosity under these cultures in the beginning of vegetation was balancing in the range of 44.8-46.0 %, and in the end of vegetation – 44.9-46.3 %. It was found out that the porosity was growing from the beginning of vegetation till the middle of it. It’s connected with development of plants’ root systems, and also with surface treatment in row-crop planting. With reduction of general porosity the volume of the capillary, as well as the non-capillary pores was reduced. With increased depth the volume of the hard phase was getting higher, but the porosity was decreasing, especially non-capillary one. With the depth, the capillary porosity was increasing, non-capillary one - decreasing. Upon the whole, the tested soil was characterized by the optimal proportion of soil phases.

It’s defined that the dynamics of nitrates under perennial grasses was developing in the following way: starting from March the nitrates quantity was gradually decreasing till the phase of blooming, that’s explained by intensive growth of vegetative mass. During the blooming phase the quantity of nitrates considerably increased and it’s connected with augmentation of the nitrogen-fixation process. After hay
crop the quantity of nitrates was reaching the maximum, and further, in the course of vegetative mass growth, the consumption of nitrogen was increasing, but nitrates content in the soil was gradually decreasing.

The crucial importance for evaluation of rotations lies in its fruitfulness, particularly in pickup of feed units and digested protein (table 2).

Table 2. Productivity of crop rotations, t/ha (average for 2018-2020 years, forest-steppe zone of The Republic of North Ossetia Alania).

| Rotation            | Culture       | Pickup of feed units. t/ha | Pickup of digested protein. t/ha |
|---------------------|---------------|----------------------------|----------------------------------|
| Grass rotation      | Oat + clover  | 9.83                       | 1.48                             |
|                     | Clover        | 9.49                       | 1.34                             |
|                     | Winter wheat  | 4.56                       | 0.39                             |
|                     | Total:        | 23.88                      | 3.21                             |
|                     | Average from 1 ha | 7.96                      | 1.07                             |
| Intertilled rotation| Potatoes      | 3.17                       | 0.36                             |
|                     | Corn          | 9.49                       | 0.48                             |
|                     | Total:        | 12.66                      | 0.84                             |
|                     | Average from 1 ha | 6.33                      | 0.42                             |

The table contains the fruitfulness indices of the tested rotations. It’s determined that the highest output of feed units was marked among the following options: 1 (oat + clover – 9.83 t/ha), 2 (clover – 9.49 t/ha), 5 (corn – 9.49 t/ha). The higher content of the digested protein was contained in clover crop, the rest cultures were approximately at the same level. According to this criteria, the low fruitfulness was defined in winter wheat crop and potatoes crop, 0.39 and 0.36 t/ha respectively (table 2). The grass rotation, where the pickup of feed units and digested protein credibly exceeded the indices of intertilled rotation, was more productive. Thus, the pickup of feed units (average from 1 ha) equaled 7.96 t/ha (grass rotation), and from intertilled one – 6.33 t/ha. Similar indices in pickup of feed units made up 1.07 and 0.42 t/ha.

4. Conclusions
The most favorable effect on soil structure was made by clover and winter wheat. Intertilled cultures had low evaluation in this context. The capacity for structure formation is more weakly expressed in potatoes.

The soil under study has good structural condition because it contains from 52.1 to 55.8% of water-stable aggregates.

Weight by volume was changing in all cultures of crop rotation depending on the period and depth of sampling. It was 0.96 g/cm³ in beginning of vegetation in case with oat + clover (average in soil layer 0-30 cm), during the phase of intensive growth – 1.13 g/cm³, but in the end of vegetation – 1.21 g/cm³. Such tendency was defined in all cultures of crop rotation.

The highest output of feed units was seen in the following options: oat + clover – 9.83 t/ha, clover – 9.49 t/ha, corn – 9.49 t/ha. The more quantity of digested protein was contained in crops of clover, the rest cultures were practically at the same level. The grass rotation where the pickup of feed units and digested protein fairly exceeded the indices of intertilled rotation (7.96 t/ha – grass rotation and 6.33 t/ha – intertilled rotation) was the more fruitful.

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