Agroecological testing of rapeseed varieties in rice crop rotation in Kalmykia

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Abstract. The article deals with the effects of nitrogen nutrition on the production of spring rape varieties and row spacing on the linear growth of plants aimed at improving the rice yield. The experimental studies were carried out on the fields of the Federal State Unitary Enterprise "Harada" in the Oktyabrsk District of the Republic of Kalmykia located in the zone of the Sarpin irrigation system. The resource-saving technologies that can increase the yield without irrigation using residual moisture reserves are of great importance. Intermediate crops can accelerate the soil cultivation on rice fields and increase the rice yield. When spring rape is sown, the soil acquires an increased ability to restore the structure of the soil layer. The green mass is digestible and contains a small amount of fiber. With a high level of moisture, it can give several yields of green mass. With intensive growth of rapeseed after mowing crops, it can be used for grazing. Over the years of research, the yield of green mass varied from 14.8 to 22.9 t/ha. It was revealed that for Vizit variety, an increase in the row spacing from 15 to 30 cm does not reduce the yield of green mass, and with an increase from 30 to 60 cm, the yield decreases by 22 ... 28%. For Ratnik variety, the best row spacing was 45 cm. An increase or decrease in row spacing reduces the green mass yield by 8 ... 12%. The influence of nitrogen nutrition and sowing density on the production process and green mass yield was identified.

1. Introduction
Currently, the irrigated area on the territory of Kalmykia’s rice irrigation systems is 22.1 thousand ha, which is 4.8% of the total area of arable land. However, the efficiency of crop cultivation on irrigated lands decreased due to the lack of funding, high cost of equipment, and the use of chemicals. In this regard, the resource-saving technologies crops which can increase the crop yield without irrigation using residual moisture are of great importance. One of such low-energy plants is spring rape (Shuravilin et al., 2011; Okonov and Dedova, 2015).

Spring rape is better than many other agricultural plants in terms of its food benefits. 1 kg of rapeseed flour contains 400-500 g of fat, 380 g of protein, which is 1.9 ... 4 times more than in pea, wheat and barley flour. A valuable feed that is not inferior to legumes in protein content is the green mass of rapeseed (1 kg contains 0.16 feed units and 30-35 g of protein, which is much more than in the green mass of corn and sunflower). Green food is characterized by good digestibility and a small
amount of fiber (Posypanov et al., 2018). With a high level of moisture, it can give 2-3 green mass yields. With intensive growth of rapeseed, it can be used for grazing.

2. Problem Statement
The following tasks were set to test spring rape varieties in Kalmykia:
- to study the effect of nitrogen nutrition on the production of spring rape varieties
- to study the effect of row spacing on the linear growth of plants
- to establish the dependence of the green mass yield on the level of nitrogen nutrition and row spacing.

3. Research Questions
The research subject is spring rapeseed varieties of different ripeness degrees - Visit, Ratnik.

4. Purpose of the Study
The purpose of the work is to study agroecological growing conditions, the production process and the green mass yield for spring rape

5. Research Methods
Field studies were carried out on the territory of the Federal State Unitary Enterprise “Harada” in the Oktyabrsk District of the Republic of Kalmykia located in the zone of the Sarpin irrigation system whose source is the Volga River (Dedova, Konieva, 2019; Nidzhilyaeva, Ochirova, 2018).

The soil cover of the experimental plot is represented by brown medium- and heavy loamy semi-desert soils characterized by the following indicators: density of the arable layer is 1.28-1.31 t/m³, in the meter layer, it is 1.69 t/m³; the smallest moisture capacity in a layer of 1.0 m is 24.84-26.72% of the mass of dry soil; the humus content in the layer of 0-0.4 m is 1.10 ... 1.24%; the nitrogen content in the arable layer is low (35.0-49.0 mg / kg), the phosphorus content is increased (35.4-40.1 mg/kg), the potassium content is high (424-460 mg/kg). The soils are saline with a chloride-sulfate type of salinization, the sum of readily soluble salts in the 0 ... 1.0 m layer is 0.101 ... 0.253%. Ground waters are chloride-sulfate-sodium-calcium with a salinity of 2.9 ... 4.2 g/l. They are located at a depth of 1.4-2.0 m (Okonov, Dedova; 2015, Melikhov, Popov, 2017).

In accordance with the research program, the field experiment involved the study of the influence of nitrogen nutrition conditions (factor A) and sowing density (factor B) on the formation of agroecological growing conditions, the production process, and the yield of green mass of spring rape of different groups of ripeness (factor C).

The experimental scheme for factor A (mineral nutrition) included the following doses of nitrogen fertilizers: option A1 - without fertilizers (control); Option A2 - application of N₉₀ to produce the planned green mass yield of 20 t/ha; option A3 - application of N₁₂₀ to produce the planned green mass yield of 25 t/ha. Against the background of nitrogen fertilizer application, four options for the feeding area (factor B) were studied: option B1 - row spacing of 15 cm; option B2 –30 cm; option B3 - 45 cm; option B4 - 60 cm. The seeding rate was 2.5 million pcs. on 1 ha. Factor C involved the studies of spring rape varieties with different ripening periods: C1 - Vizit (early); C2 - Ratnik (mid-season).

The experiment was carried out by the method of organized repetitions which included plots with a complete set of all variants. The number of repetitions was three. Within the organized repetition, the experimental variants for the main plots and sub-plots were placed by the method of randomization. The size of the plots was 50 m² with a total area of 0.36 ha.

Fertilizer rates were calculated by the generally accepted balance method (Mineev, 2004; Filin, Okonov, 2004) for the planned crop using the recommended application rates for soil nutrients and mineral fertilizers.
6. Findings

Formation of the green mass yield is associated with a linear growth of plants. In the first 30 days of vegetation, plants grew slowly, their height varied from 5 to 12 cm. Rapeseed plants grew more actively in the second month of vegetation after the phenological phase of 2 ... 3 leaves; then, growth intensity decreased.

For the decade after the “stretching” phase, a daily increase in the ground mass of plants varied from 5.3 to 15.2 cm. The largest increase was observed in 2018, which was more favorable in terms of precipitation. There were 449 mm of precipitation during this period. It was 52 ... 95% higher than in 2016-2017.

According to the experimental variants, the best growth was observed in the mid-ripening Ratnik variety with a nitrogen supply level of N\textsubscript{120} and a row spacing of 45 cm (1.2 ... 1.5 cm). In the early ripening variety Vizit with the same nitrogen rate and a row spacing of 15 cm, the growth was 1.3-1.9 cm.

Varieties with different ripeness periods grow unequally intensively. In the early-ripening variety Vizit, the maximum growth of 3.34 ... 5.17 cm was observed on 32 ... 35 days after germination. Moreover, the linear growth depended on the nitrogen nutrition and varied from 3.49 to 5.02 cm / day (Figure 1).

![Figure 1](image_url)

*Figure 1. Dynamics of the average daily linear growth of spring rape depending on nitrogen nutrition*
The highest growth in Ratnik was observed on 42 ... 45 days after germination, which coincides with the period of budding - mowing ripeness. The maximum value of linear growth was observed in 2018 for all variants - 2.89 ... 4.58 cm/day. Depending on the level of nitrogen fertilizers, for 2016-2018, the average growth was 2.60 ... 4.12 cm/day which is 0.13 ... 0.45 cm / day more than for the same period in Visit variety. The linear growth of spring rape slowed down and stopped during the formation of reproductive organs.

The index of the leaf surface determines absorption of sunlight as the main factor which determines the value of green rape mass (Table 1).

Table 1. Leaf surface area of agrocenosis of spring rape during mowing ripeness, thousand m²/ha, average for 2016-2018

| Factor A: Nitrogen | Factor B: row spacing, cm | Variety |
|--------------------|---------------------------|---------|
|                    | 15 | 23.8 | 25.6 |
|                    | 30 | 22.9 | 23.8 |
|                    | 45 | 24.1 | 24.2 |
|                    | 60 | 23.1 | 22.1 |
|                    | 15 | 28.0 | 32.1 |
|                    | 30 | 39.1 | 30.4 |
| N₉₀                | 45 | 32.4 | 29.7 |
|                    | 60 | 30.1 | 28.9 |
|                    | 15 | 31.3 | 33.4 |
|                    | 30 | 33.1 | 32.8 |
|                    | 45 | 34.2 | 31.2 |
|                    | 60 | 33.8 | 30.5 |
| N₁₂₀               | 15 | 18.50 | 17.77 | 19.86 | 18.71 |
|                    | 30 | 17.13 | 16.45 | 18.39 | 17.32 |
|                    | 45 | 16.65 | 15.99 | 17.88 | 16.84 |
|                    | 60 | 15.86 | 15.23 | 17.03 | 16.04 |
|                    | 15 | 20.08 | 19.26 | 21.54 | 20.29 |
|                    | 30 | 19.70 | 18.92 | 21.15 | 19.92 |
|                    | 45 | 19.15 | 18.39 | 20.56 | 19.37 |
|                    | 60 | 19.64 | 18.81 | 19.88 | 19.44 |
|                    | 15 | 20.94 | 20.10 | 22.48 | 21.17 |
|                    | 30 | 20.56 | 19.74 | 22.07 | 20.79 |
|                    | 45 | 20.55 | 19.26 | 21.71 | 20.50 |
|                    | 60 | 20.38 | 19.14 | 21.68 | 20.31 |
|                    | 15 | 14.25 | 14.05 | 16.21 | 14.84 |
|                    | 30 | 15.25 | 14.90 | 17.51 | 15.89 |
|                    | 45 | 15.68 | 15.45 | 17.83 | 16.32 |
|                    | 60 | 15.11 | 14.82 | 17.18 | 15.70 |
|                    | 15 | 17.10 | 16.86 | 19.45 | 17.80 |
|                    | 30 | 18.30 | 17.88 | 21.40 | 19.19 |
|                    | 45 | 18.82 | 18.56 | 21.38 | 19.58 |
|                    | 60 | 18.13 | 17.78 | 20.62 | 18.84 |
|                    | 15 | 19.67 | 19.40 | 22.37 | 20.48 |
|                    | 30 | 21.04 | 20.56 | 24.16 | 21.92 |
|                    | 45 | 22.58 | 21.32 | 24.61 | 22.84 |
|                    | 60 | 20.85 | 20.45 | 23.71 | 21.67 |
During the mowing ripeness, the foliage of rapeseed plants varied from 22.1 to 34.2 thousand m\(^2\)/ha. The largest leaf surface area was formed by plants when using nitrogen N\(_{120}\) in the amount of 30.5-34.2 thousand m\(^2\)/ha, which is 8.6 ... 9.2 thousand m\(^2\)/ha more than in the control variant, and 3.3 ... 4.2 thousand m\(^2\)/ha more than when using nitrogen at a dose of 90 kg/ha.

The average green yield of spring rape varied from 14.8 to 22.9 t/ha (Table 2).

In 2018, the highest yield of green mass was observed in Ratnik with N\(_{120}\) and a row spacing of 45 cm - 24.61 t/ha, which is 1.4 times higher compared to the control variant, where the yield varied from 16.2 to 17.8 t/ha. The yield of green mass in Visit varied from 17.03 to 22.48 t/ha. Moreover, low yields were observed with a row spacing 60 cm in the control variant - 15.23 ... 17.03 t/ha.

In 2017, the smallest green mass yield was observed in all experiment variants (14.05 ... 21.32 t/ha) due to the low amount of precipitation (32.8 mm) during the period of aboveground mass formation. During the same period of 2016, there were 74.8 mm of precipitation; in 2018, there were 90.6 mm of precipitation. In general, in Visit, an increase in the row spacing from 15 to 30 cm does not reduce the yield of green mass, but with an increase from 30 to 60 cm, this value decreases by 22 ... 28%. For Ratnik, it was revealed that the best row spacing is 45 cm. Increasing or decreasing the row spacing decreases the yield of the aboveground mass by 8 ... 12%.

Thus, the method of multiple regression analysis using STATISTICA 6.0 allowed us to obtain a model of a nonlinear dependence of the green mass yield on the level of nitrogen nutrition and a row spacing.

### Table 3. The discrepancy between the actual and model data on the yield of green mass of spring rape

| Nitrogen level, kg/ha | Row spacing, cm | Yield, t/ha | Discrepancy, % |
|-----------------------|-----------------|-------------|----------------|
|                       |                 | actual      | calculated     |                |
|                       |                 | Ratnik      |                |
| without fertilizers   | 15              | 14.84       | 14.7           | 1.0            |
| (control)             | 30              | 15.89       | 16.1           | 1.3            |
|                       | 45              | 16.32       | 16.5           | 1.1            |
|                       | 60              | 15.70       | 15.6           | 0.6            |
|                       | 15              | 17.80       | 17.9           | 0.5            |
|                       | 30              | 19.19       | 19.3           | 0.6            |
|                       | 45              | 19.58       | 19.6           | 0.1            |
|                       | 60              | 18.84       | 18.7           | 0.7            |
| N\(_{90}\)            | 15              | 20.48       | 20.8           | 1.6            |
|                       | 30              | 21.92       | 22.2           | 1.3            |
|                       | 45              | 22.84       | 22.4           | 1.9            |
|                       | 60              | 21.67       | 21.5           | 0.8            |
| N\(_{120}\)           | 15              | 18.71       | 18.6           | 0.6            |
|                       | 30              | 17.32       | 17.6           | 1.6            |
|                       | 45              | 16.84       | 16.8           | 0.2            |
|                       | 60              | 16.04       | 16.3           | 1.6            |
|                       | 15              | 20.29       | 19.4           | 4.3            |
|                       | 30              | 19.92       | 18.8           | 2.9            |
|                       | 45              | 19.37       | 18.4           | 5.0            |
|                       | 60              | 19.44       | 18.3           | 5.8            |
|                       | 15              | 21.17       | 19.3           | 8.8            |
|                       | 30              | 20.79       | 18.8           | 9.5            |
|                       | 45              | 20.50       | 18.6           | 9.2            |
|                       | 60              | 20.31       | 18.6           | 8.4            |

An analysis of model reliability (Table 3) shows that discrepancies between the actual data and calculation results are less than 10%, and the correlation coefficient R between them is 0.72.
7. Conclusion

The following conclusions can be made.

According to the experimental variants, the best growth was observed in the mid-ripening Ratnik variety with a nitrogen supply level of N\textsubscript{120} and a row spacing of 45 cm - 1.2 ... 1.5 cm; in the early ripening variety Visit with the same nitrogen rate and a row spacing of 15 cm, the growth was 1.3-1.9 cm.

The average yield of spring rape green mass varied from 14.8 to 22.9 t / ha.

In general, it was found that in Vizit, an increase in row spacing from 15 to 30 cm does not reduce the yield of green mass, but with an increase in row spacing from 30 to 60 cm, this value decreases by 22 ... 28%. For Ratnik, the best row spacing is 45 cm. An increase or decrease in row spacing decreases the yield of the ground mass by 8 ... 12%.

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