Improving Yield of Non-Perennial Crops in the Conditions of Yakutia Using Different Doses of Mineral Fertilizers

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Abstract. Providing sustainable feed supplies is the main condition for the high productivity of the livestock industry. Feed supplies shall meet the needs of farm animals. The application effectiveness of mineral fertilizers is one of the most important factors of technology ensuring the improvement of yield, chemical composition, and nutritional value of feed. The article presents the results of research on the effectiveness of different doses of mineral fertilizers used to improve the yield of non-perennial fodder crops in the conditions of Yakutia. Experiments were held in 2015–2016 in the Moydoch plot of the Khangalassky District. Non-perennial fodder crops were sown on June 1. Sowing was done by drilling with 46 cm inter-row spacing for corn and sunflower, 30 cm for oil radish and sudangrass, and 15 cm for millet. The sowing depth was 4–6 cm for non-perennial fodder crops, and 2–3 cm for oil radish. The experience of application of mineral fertilizers to improve the yield of non-perennial crops has shown primary affecting factors: the first factor — non-perennial crops variety (corn, sunflower, millet, sudangrass, oil radish), the second factor — mineral fertilizer dose (reference, (NPK)₉₀ kg/ha, (NPK)₁₂₀ kg/ha of primary nutrient). On average during two years of studies, corn crops have shown the highest fresh yield with mineral fertilizers applied at an NPK₁₂₀ kg/ha dose of 9.7 t/ha; sunflower — 14.6 t/ha; millet — 6.1 t/ha, oil radish — 12.2 t/ha, and sudangrass — 7.6 t/ha with fertilizers applied at an NPK₉₀ kg/ha dose. NPK₁₂₀ kg/ha dose of mineral fertilizers ensured high nutrient content in the crops of corn, millet, oil radish, and sudangrass, and NPK₉₀ kg/ha for sunflower. Sunflower and oil radish have shown the best nutritional value from all the studied species of non-perennial fodder crops.
1. Introduction
Providing sustainable feed supplies ensuring balanced animal feed throughout the year is a priority task for the high productive livestock industry. Feed supplies shall meet the needs of animals, both quantitative and qualitative. The application effectiveness of mineral fertilizers is one of the most important factors of technology ensuring the improvement of yield, chemical composition, and nutritional value of feed [7, 8]. Identifying proper doses is the main condition for the successful use of mineral fertilizers. Therefore, finding proper mineral fertilizer doses for the cultivation of promising non-perennial crops is an urgent problem in the republic.

The purpose of the research is to study the improvement of non-perennial crop yields by using different doses of mineral fertilizers in the conditions of Yakutia.

2. Research objectives:
- study the effectiveness of different doses of mineral fertilizers used to improve yields of non-perennial crops;
- determine the chemical composition and nutritional value of corn, sunflower, millet, sudangrass, and oil radish.

3. Research methods
Experiments on the effectiveness of mineral fertilizers used to improve yields of non-perennial crops were held in 2015–2016 in the Moydoch plot of Khangalassky District.

Research subjects were non-perennial fodder crops (corn, sunflower, millet, sudangrass, oil radish) and mineral fertilizers.

The experimental plot has slightly saline cryosolic soils forming isolated spots of scarce vegetation according to D.D. Savvinov [9]. The soil has alkaline pH of 8.55, containing 2.64% of humus and 0.29% of total nitrogen in the 0–20 cm layer; 164 mg of mobile phosphorus ($P_2O_5$) per kg of soil, and 280 mg/kg exchangeable potassium ($K_2O$) per kg of soil.

Technological operations of forage crops cultivation were carried out according to the methodological manual for farming in the Republic of Sakha (Yakutia) [10]. Non-perennial fodder crops were sown on June 1. Sowing was done by drilling with 46 cm inter-row spacing for corn and sunflower, 30 cm for oil radish and sudangrass, and 15 cm for millet. The sowing depth was 4–6 cm for non-perennial fodder crops, and 2–3 cm for oil radish.

The experience of application of mineral fertilizers to improve the yield of non-perennial crops has shown to primary affecting factors: factor A — non-perennial crops variety (corn, sunflower, millet, sudangrass, oil radish), factor B — mineral fertilizer dose (reference, (NPK)$_{90}$ kg/ha, (NPK)$_{120}$ kg/ha of primary nutrient). The experiment included 15 alternative cases with four repetitions. Registration plot area — 28 m². The experiments were carried out with an irrigation rate of 250 m³/ha at HB below 70%.

The registration and observations were carried out according to the method of the All-Russian Research Institute of Feed Industry [2, 3, 4, 5]. Chemical tests were performed in the laboratory of processing and bulk analysis of Yakutsk Research Institute of Agriculture using the SpectraStar analyzer. Statistical data were processed using the dispersion analysis according to B.A. Dospekhov [1]. Corn, sudangrass, and millet were harvested at the milk-wax ripeness stage, while sunflower and oil radish — at the flowering stage. Weather conditions of 2015–2016 were favorable for the growth and development of non-perennial fodder crops.

4. Research results
The yield of non-perennial fodder crops depended in many respects on weather conditions, types and doses of mineral fertilizers.

Corn is known to be highly responsive to mineral fertilizers. Over the years of research, we have found that high fresh yields of corn are obtained by applying mineral fertilizers in a (NPK)$_{120}$ kg/ha dose of 9.7 t/ha of fresh yield, which exceeds the reference value of 2.0 t/ha of fresh yield. Fresh
yields of corn with fertilizers applied at an (NPK)\textsubscript{90} kg/ha dose were lower by 14.4\% compared to case when fertilizers were applied at an (NPK)\textsubscript{120} kg/ha dose (Table 1).

Table 1. Yields of non-perennial fodder crops depending on mineral fertilizer dose (average values for 2015–2016).

| Crop       | Mineral fertilizer application | Average fresh yield, t/ha |
|------------|--------------------------------|--------------------------|
| Corn       | Reference                      | 7.7                      |
|            | (NPK)\textsubscript{90}        | 8.3                      |
|            | (NPK)\textsubscript{120}      | 9.7                      |
| Sunflower  | Reference                      | 12.1                     |
|            | (NPK)\textsubscript{90}        | 14.6                     |
|            | (NPK)\textsubscript{120}      | 13.7                     |
| Millet     | Reference                      | 4.5                      |
|            | (NPK)\textsubscript{90}        | 6.1                      |
|            | (NPK)\textsubscript{120}      | 5.4                      |
| Oil radish | Reference                      | 9                        |
|            | (NPK)\textsubscript{90}        | 12.2                     |
|            | (NPK)\textsubscript{120}      | 11.2                     |
| Sudangrass | Reference                      | 6.2                      |
|            | (NPK)\textsubscript{90}        | 7.6                      |
|            | (NPK)\textsubscript{120}      | 6.8                      |

HCP\textsubscript{05} (factor A) — 1.1; (factor B) — 1.2

High fresh yields of sunflower (14.6 t/ha), millet (6.1 t/ha), oil radish (12.2 t/ha), and sudangrass (7.6 t/ha) are ensured by applying mineral fertilizers in an (NPK)\textsubscript{90} kg/ha dose. The application of mineral fertilizers in an (NPK)\textsubscript{120} kg/ha dose is a bit inferior to an (NPK)\textsubscript{90} kg/ha dose in terms of fresh yield: sunflower by 6.1\%, millet — 11.4\%, oil radish — 8.2\%, sudangrass — 10.5\%. The reference yields were much lower compared to yields of crops grown with mineral fertilizers.

Among the studied cases of non-perennial fodder crops, the highest fresh yields were shown by sunflower at different doses of mineral fertilizers from 13.6 to 14.6 t/ha.

The chemical composition of green fodder depends on its botanical composition, growing conditions and locations, and the applied farming techniques. The study of the chemical composition of non-perennial crops showed that nutrients differ by the crop variety, as well as the mineral fertilizer dose.

Our experiments have shown that sunflower and oil radish had the highest nutrient content among the studied non-perennial crops. The nutritional value of the reference cases is much lower compared to crops grown with mineral fertilizers applied in (NPK)\textsubscript{90}, (NPK)\textsubscript{120} doses.

The nutritional value of cereal crops corresponds to the regulated value for livestock but is inferior to the nutritional value of oil radish and sunflower.

The high nutrient content in corn crops was ensured by applying mineral fertilizers in an (NPK)\textsubscript{120} dose: fodder units — 0.60, exchangeable energy — 8.68 MJ, gross energy — 18.9 MJ per kg of dry matter, digestible protein content — 153.1 g per 1 fodder unit (Table 2). The nutritional value of corn with mineral fertilizers applied in an (NPK)\textsubscript{90} dose is a bit inferior to (NPK)\textsubscript{120}, while the digestible protein content reaches 149 g per 1 fodder unit.

Similar behavior is noted for millet and sudangrass crops. With mineral fertilizers applied in an (NPK)\textsubscript{120} dose, millet crops have a high content of fodder units — 0.66, exchangeable energy — 9.3 MJ, gross energy — 19.3 MJ per kg of dry matter. Also, with mineral fertilizers applied in an
(NPK)\textsubscript{120} dose, sudangrass shows the highest content of fodder units — 0.61, exchangeable energy — 8.74 MJ, gross energy — 18.9 MJ per kg of dry matter, digestible protein content — 145.4 g per 1 fodder unit.

Fresh yields of oil radish and sunflower have high nutritional values. Mineral fertilizers have the primary effect on the accumulation of nutrients in the herbage. With mineral fertilizers applied in an (NPK)\textsubscript{90} dose, the content of fodder unit in sunflower reaches 0.69, exchangeable energy — 9.67 MJ, gross energy — 19.3 MJ per kg of dry matter, digestible protein content — 141.4 g per 1 fodder unit (Table 2). The nutritional value of sunflower with mineral fertilizers applied in an (NPK)\textsubscript{120} dose is inferior to the nutritional value at an (NPK)\textsubscript{90}.

Table 2. Nutritional value of fodder crops depending on mineral fertilizer dose (average values for 2015–2016).

| Case           | Dry matter per 1 kg | Available energy, MJ | Gross energy, MJ | Digestible protein in 1 fodder unit, g |
|----------------|---------------------|----------------------|------------------|---------------------------------------|
| Corn           |                     |                      |                  |                                       |
| Reference      | 0.57                | 8.61                 | 18.8             | 129.7                                 |
| (NPK)\textsubscript{90} | 0.60                | 8.64                 | 18.9             | 149.0                                 |
| (NPK)\textsubscript{120} | 0.60                | 8.68                 | 18.9             | 153.1                                 |
| Sunflower      |                     |                      |                  |                                       |
| Reference      | 0.63                | 9.49                 | 19.2             | 116.3                                 |
| (NPK)\textsubscript{90} | 0.69                | 9.67                 | 19.3             | 134.6                                 |
| (NPK)\textsubscript{120} | 0.68                | 9.30                 | 19.3             | 141.4                                 |
| Millet         |                     |                      |                  |                                       |
| Reference      | 0.62                | 9.01                 | 18.9             | 133.2                                 |
| (NPK)\textsubscript{90} | 0.64                | 9.06                 | 19.1             | 151.1                                 |
| (NPK)\textsubscript{120} | 0.66                | 9.07                 | 19.0             | 148.1                                 |
| Oil radish     |                     |                      |                  |                                       |
| Reference      | 0.64                | 8.93                 | 18.6             | 137.6                                 |
| (NPK)\textsubscript{90} | 0.64                | 8.97                 | 18.6             | 151.5                                 |
| (NPK)\textsubscript{120} | 0.69                | 9.25                 | 18.8             | 151.4                                 |
| Sudangrass     |                     |                      |                  |                                       |
| Reference      | 0.60                | 8.64                 | 18.8             | 136.1                                 |
| (NPK)\textsubscript{90} | 0.61                | 8.71                 | 18.9             | 140.3                                 |
| (NPK)\textsubscript{120} | 0.61                | 8.74                 | 18.9             | 145.4                                 |

The high nutrient content in the oil radish crops is ensured by mineral fertilizers applied in an (NPK)\textsubscript{120} dose. The content of fodder units reached 0.69, exchangeable energy — 8.74 MJ, gross energy — 18.9 MJ per kg of dry matter, digestible protein — 151.4 g in 1 fodder unit. Similar data were obtained for an (NPK)\textsubscript{90} dose of mineral fertilizers. Thus, the nutritional value of fodder crops depends on the species of non-perennial fodder crops and doses of mineral fertilizers.

5. Conclusions

Our research has shown that the cultivation of promising non-perennial fodder crops with the use of mineral fertilizers in certain doses results in a reliable improvement of fresh yields. Corn crops have shown the highest fresh yield with mineral fertilizers applied at an NPK\textsubscript{120} kg/ha dose of 9.7 t/ha; sunflower — 14.6 t/ha, millet — 6.1 t/ha, oil radish — 12.2 t/ha, and sudangrass — 7.6 t/ha with fertilizers applied at an NPK\textsubscript{90} kg/ha dose. NPK\textsubscript{120} kg/ha dose of mineral fertilizers ensured high nutrient content in the crops of corn, millet, oil radish, and sudangrass, and NPK\textsubscript{90} kg/ha for sunflower.
Sunflower and oil radish have shown the best nutritional value from all the studied species of non-perennial fodder crops.

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