Agrobiological evaluation of narrow-leaved lupin varieties in the conditions of the Middle Urals

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Abstract. Research and production introduction of the multipurpose use of narrow-leaved lupin varieties in fodder production in the region will increase the agricultural efficiency with developed dairy cattle breeding. The aim of the research was to study the adaptive properties of narrow-leaved lupin varieties in the Udmurt Republic, to analyze the efficiency of its cultivation. The studies were carried out in the southern agroclimatic region of the Udmurt Republic on gray forest soil. The arable soil layer was characterized by a humus content of 2.1-2.6%, mobile phosphorus - 100-101 mg/kg of soil, mobile potassium - 101-170 mg/kg of soil, and pH of from moderately acidic to almost neutral (5.0 - 5.6). By the content of crude protein (32%) in grain, narrow-leaved lupin is the leader in the region among leguminous crops. During the research period, a relatively high yield of 1.36-4.95 t/ha was formed by Snezhet' variety. Varieties Snezhet' and Vector (S2d = 0.05...0.14) were distinguished by their high resistance to changes in agro-ecological conditions. The combination of ecological plasticity indicators (bi = 0.60) and phenotypic stability (S2d = 0.60) of Crystal variety indicates its high adaptive properties.

1. Introduction
Legumes are a source of valuable vegetable protein and one of the important links in the process of biologization and crop raising greening. Narrow-leaved lupin (Lupinus angustifolius L.) is a crop adapted to changes in a wide range of climatic conditions. For many centuries, it was used mainly as a green manure plant, since the success and prospects of the multipurpose species' use depend on its breeding improvement, in particular, on the content of a certain level of alkaloids in seeds and green mass [1]. This crop can be successfully cultivated for multipurpose use. Its inclusion in agroecosystems makes it possible to increase the content of fodder protein of plant origin in concentrated feed. Narrow-leaved lupin is the leader in the collection of digestible protein (482.6 - 601.6 kg/ha). At the same time, the nitrogen cycle's greening in the agroecosystem takes place due to the biological fixation of nitrogen in the air [2].

For the replication of narrow-leaved lupin in agricultural production, it is necessary to study agrobiological features and technology of its cultivation. Antsiferova O.A. and Kharitonova E.N. [3] established its reaction to soil-geomorphological factors and agrochemical soil properties. The yield of green and air-dry mass of lupin, the density of plants per unit area and their height are the most sensitive to increased acidity. The adaptation of lupin plants to arid conditions is in increasing the roots' proportion in the plant phytomass. In the conditions of increased moisture supply, close positive correlation relations were established between grain yield and aboveground mass, grain productivity and dry matter yield with photosynthetic potential and the number of nodules. Under favorable moisture supply conditions, a relationship was established at a high level of dry matter yield with leaf area and photosynthetic...
potential. In arid conditions, there was a negative correlation between the leaf area, photosynthetic potential and the number of nodules due to competition for plastic substances. Ageeva P.A. et al. [5, 6] found that under conditions of arid hydrothermal regime, narrow-leaved lupin is capable of forming a grain yield of 2.5 t/ha, green mass - 38.0 t/ha. To reduce the impact of external factors on the productivity formation of field crops, an adaptive cultivation technology is required. The studies of V.L. Bopp [4] recorded 10 species of vegetal vegetation belonging to the spring biological group with narrow-leaved lupin in the agrocenosis. The dominant weeds are amaranth (species), panicgrass (species) 57 pcs/m². The biological efficiency of Lazurit herbicide was 71.9% at which the maximum yield of green mass was obtained at 14.3 t/ha.

Academician A.A. Zhuchenko [7] proved that the correct organization of the "plant - environment" ecosystem determines a significant increase in profit from a unit of used area. At the same time, he assigned a large role to the agroecological zoning of the territory, which makes it possible to fully realize the potential of varieties and crops. Nikolai Ivanovich Vavilov also noted: "The harvest is a derivative of the environment and genotype and is largely determined by the crop conditions, the conditions of the region." The results of scientific research and production practice convincingly prove that in the total share of agricultural crops' productivity increase, a variety or hybrid accounts for about 25-50%. Scientists have proven that the introduction of new varieties or hybrids into production contributes to an increase in yield by about 1% [8].

This crop has been little studied in the conditions of the Udmurt Republic. Considering that the main task of the region's agro-industrial complex is represented by the development of dairy cattle breeding - the provision of farm animals with self-produced feed in full is a very urgent task. And in this case, the efficiency of agricultural development determines the selection of field crops and varieties of universal use, ensuring obtaining high-quality forage [9]. Studies carried out in the region have proven the effectiveness of the introduction of varieties and hybrids of field crops [10]. In this case, it is necessary to carry out a comprehensive analysis.

Currently, narrow-leaved lupin is of great interest for fodder production in the Udmurt Republic. In this regard, the issue of studying the adaptability of varieties and the effectiveness of crop cultivation is of great scientific and practical importance.

The aim of the research was to study the crops' adaptive properties in the Udmurt Republic, to analyze the cultivation efficiency of narrow-leaved lupin varieties.

The research methodology was generally accepted in accordance with the State Variety Testing Methodology. The studies were carried out in the southern agroclimatic region of the Udmurt Republic on gray forest soil. The arable soil layer was characterized by a humus content of 2.1-2.6%, mobile phosphorus - 100-101 mg/kg of soil, mobile potassium - 101-170 mg/kg of soil, and pH KCl from moderately acidic to almost neutral (5.0 -5.6).

2. Research results
Leguminous crops are used in compound feeds as sources of protein; they are high in protein, fats and carbohydrates. Compared to cereals, legumes contain 2-3 times more protein and amino acids, fat and fatty acids, but less carbohydrates. According to the protein content in leguminous crops, their value as a protein feed is determined (table 1).

| Indicators          | Narrow-leaved lupin | Sowing peas | Common vetch |
|---------------------|---------------------|-------------|--------------|
| Dry matter, %       | 87.0                | 88.0        | 86.0         |
| Exchange energy, MJ/kg | 9.6                 | 10.3        | 10.1         |
| Crude protein, %    | 32.0                | 21.3        | 24.3         |
| Crude fat, %        | 3.7                 | 1.8         | 1.5          |
| Linoleic acid, %    | 1.5                 | 0.6         | 0.4          |
| Starch, %           | 26.5                | 28.9        | 38.3         |
Comparative analysis of nutritional value allows to conclude about the advantage of narrow-leaved lupin in terms of crude protein content (32.0%) relative to leguminous crops (21.3-24.3%) common in the region. The studies of P.A. Ageeva [11] revealed the maximum protein harvest with a grain yield of 1,003 kg/ha. A similar trend was revealed in the content of crude fat, the advantage over the studied legumes is 1.9-2.2% in grain. The yield of narrow-leaved lupin varieties over the years of research had a significant variation, as evidenced by the collection of dry matter of Crystal variety of 5.26 t/ha and 0.81 t/ha of Pheasan variety (Table 2).

### Table 2. Dry matter yield of narrow-leaved lupin varieties, t/ha.

| Variety | 2005   | 2006   | 2007   | 2008   | 2009   | 2010   | 2011   | 2012   | 2013   |
|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Snezhet’| 4.95   | 3.51   | 2.67   | 2.75   | 1.36   | 1.41   | -      | -      | -      |
| Crystal | 5.26   | 3.00   | -      | -      | 1.20   | 1.10   | 2.70   | 1.91   | 0.84   |
| Vector  | -      | -      | -      | -      | 2.01   | 2.24   | -      | -      | -      |
| Pheasan | -      | -      | -      | -      | -      | -      | 2.81   | 2.28   | 0.81   |
| LSD05   | 0.31   | 0.37   | 0.17   | 0.32   | 0.12   | 0.06   | 0.20   | 0.08   | 0.16   |

During the research period, a relatively high yield of 1.36-4.95 t/ha was formed by Snezhet’ variety. This variety formed a significantly high yield of 0.51 t/ha or 17% in 2005 (LSD05 = 0.37 t/ha), 0.16 t/ha or 13% in 2009 (LSD05 = 0.12 t/ha), 0.31 t/ha or 28% in 2010 (LSD05 = 0.06 t/ha) relative to the yield of Crystal variety. Vector variety was studied in 2007-2008, which was inferior in productivity to Snezhet’ variety by 0.51-0.66 t/ha or by 23-33% with LSD05 = 0.17-0.32 t/ha. Pheasan variety was at the level of Crystal variety in terms of forage productivity.

As a result of the research, it was revealed that the studied varieties of narrow-leaved lupin differed in the duration of the growing season from sowing to harvesting ripeness. Vector variety was characterized by a relatively long growing season of 52 days, which was 8-12 days more than other studied varieties. Crystal and Snezhet’ varieties had the shortest growing season of 40 days (Table 3). In terms of resistance to lodging, drought, and plant height, the varieties did not differ significantly.

### Table 3. Economically useful traits of narrow-leaved lupin varieties.

| Variety   | Lodging resistance, score | Vegetative period, days | Plant height, cm | Root rot prevalence, % | Drought resistance, score |
|-----------|---------------------------|-------------------------|------------------|------------------------|---------------------------|
| Snezhet’  | 5                         | 40                      | 40               | 6.3                    | 4                         |
| Crystal   | 5                         | 40                      | 39               | 8.2                    | 4                         |
| Vector    | 5                         | 52                      | 40               | 4.5                    | 5                         |
| Pheasan   | 5                         | 44                      | 42               | 4.0                    | 4                         |

Root rot affects lupin seedlings and adult plants. In seedlings, rotting affects roots and stems near the root collar and cotyledons. Seedlings turn brown and often die before reaching the soil surface. In affected plants that have appeared on the surface, the cotyledons are covered with deep brown ulcer-like wounds, sometimes the growing point darkens. In older plants, the roots and base of the stem turn black and die off. Such plants are stunted and usually wither. As a result of the research, it was revealed that Crystal variety was characterized by the highest prevalence of root rot (8.2%), the least damage was in the plants of Pheasan variety (4.0%).
It is believed that high selection efficiency in breeding is expected for traits, the variability of which is largely due to the genotype. In our studies, environmental factors had the greatest contribution to the yield of 92.9% (Figure 1).

The proportion of the interaction “genotype × external environment” was insignificant in the formation of the green mass yield (4.1%), which proves a significant variation in traits depending on the prevailing conditions. Studies have revealed the greatest contribution of the genotype (24.0%) to the prevalence of root rot on narrow-leaved lupin plants. Therefore, when choosing varieties of narrow-leaved lupin for cultivation in the Udmurt Republic, it is necessary, first, to consider the resistance to root rot and to provide seed incrustation against pathogens - fungi from the \textit{Fusarium} genus - in the cultivation technology.

![Figure 1](image_url)

**Figure 1.** The contribution of the studied factors to the variability of the main quantitative traits of narrow-leaved lupin.

Since the variability of the main quantitative traits of narrow-leaved lupin is influenced by external environmental factors, it is necessary to establish their stress resistance, plasticity, and stability for the selection of adaptive varieties.

Stress resistance is determined by the difference between the minimum and maximum values of the indicator. The smaller this gap, the higher the resistance of the variety to stressful growing conditions. Among the studied varieties, Snezhet’ was characterized by stress resistance, the yield decrease in unfavorable conditions was 49% (Figure 2). Pheasan variety has a low resistance to changes in conditions as evidenced by the range of dry matter yield of 71%.
Figure 2. Parameters of ecological plasticity of narrow-leaved lupin varieties.

An indicator that shows the reaction rate of the genotype under changing environmental factors is the coefficient of ecological plasticity (bi). The higher the coefficient of ecological plasticity (bi > 1), the higher the responsiveness of this variety. Such varieties place high demands on the cultivation technology. The stability coefficient (S²d) indicates the adaptive response of the genotype, leading to the correspondence of changes in the state of traits and properties of the organism to changes in agro-ecological conditions. They are characterized by the degree of its stability [3].

Crystal variety was characterized by a weak responsiveness to changes in meteorological and edaphic conditions; the coefficient of ecological plasticity (bi = 0.60) was less than 1.0.

Varieties Snezhet’ and Vector (S²d = 0.05...0.14) were distinguished by their high resistance to changes in agro-ecological conditions. The combination of ecological plasticity indicators (bi = 0.60) and phenotypic stability (S²d = 0.60) of Crystal variety indicates its high adaptive properties.

3. Conclusion
Thus, the use of narrow-leaved lupin for feed in the form of grain, green mass or silage allows reducing the amount of concentrates in the diets and enriching the feed with proteins (content in grain is 32%). Assessment of the varieties' adaptability and the economic efficiency of cultivation makes it possible to select them correctly. In this case, relying on long-term research on the yield of green mass of 12.1 t/ha, it can be recommended to cultivate the narrow-leaved lupin variety Snezhet’ in production.

References
[1] Vishnyakova M A 2020 Alkaloids of narrow-leaved lupin as a factor determining alternative ways of the crop's using and breedingVavilov Journal of Genetics and Breeding 24 (6) 625-635
[2] Yastrebova A V 2020 Comparative assessment of adaptive properties and the efficiency of narrow-leaved lupin varieties' cultivation Bulletin of the Izhevsk State Agricultural Academy 4 (64) 12-19
[3] Antsiferova O A 2016 Influence of soil-agrochemical factors on the productivity of lupin (Lupinus angustifolius) in experimental sowing Bulletin of KSTU 43 167-177
[4] Bopp V L 2020 Narrow-leaved lupin: the effect of herbicides and fertilizers on the productivity of green mass *Bulletin of KrasGAU* **5** (158) 73-79

[5] P A Ageeva M V Matyukhina N A Pochutina O M Gromova 2020 Results and prospects of green manure varieties' selection of narrow-leaved lupin at the All-Russian Research Institute of Lupine *Legumes and cereals* **2** (34) 59-63

[6] Agarkova S N 2019 Formation of productivity by narrow-leaved lupin varieties in contrasting meteorological conditions *Legumes and cereals* **1** (29) 31-37

[7] Zhuchenko A A 2000 *Fundamental and applied scientific priorities of adaptive intensification of crop production in the 21st century* Saratov 276

[8] Babaytseva T A 2017 Ecological plasticity of winter triticale collection samples for winter hardiness *Grain farming in Russia* **6** 7-11

[9] S I Kokonov G Y Ostaev R D Valiullina T N Ryabova I A Mukhina A I Latysheva A A Nikitin 2019 Agroecological and economic assessment of corn hybrids in the Udmurt Republic *Indo American Journal of Pharmaceutical Sciences* **4** 8198-8204

[10] Kokonov S I 2019 Agroecological Assessment of Perennial Ryegrass Varieties in the Conditions of the Udmurt Republic *Digital agriculture - development strategy Proceedings of the International Scientific and Practical Conference. "Advances in Intelligent Systems Research"* 254-257

[11] Ageeva P A 2020 Narrow-leaved lupin - a source of valuable nutrients for use in feed production *Feed production* **10** 29-33