BIOLOGICAL POTENTIAL OF WINTER HYBRID RYE: ADAPTIVE MECHANISMS AND PROSPECTS FOR USE IN THE FOREST-STEPPE OF UKRAINE

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Contemporary challenges in agricultural production, related to global climate change, soil degradation, and the growing demand for high-quality grain, require new approaches to crop breeding and cultivation. One of the promising areas in crop production is the use of hybrid forms that combine high productivity with increased resistance to adverse environmental factors. Hybrid winter rye occupies a special place among them – a crop that is capable not only of providing stable yields in extreme conditions, but also of forming a new quality of grain production [1, 2].

The biological potential of hybrid winter rye is determined by unique adaptive mechanisms: exceptional winter hardiness and tolerance to soil acidity, efficient use of moisture, and increased resistance to pathogens. This makes the crop an important element in the strategy of adaptive agriculture, especially in the context of climate change in Ukraine and the world as a whole [3].

The relevance of the study is also determined by the fact that, against the backdrop of growing competition in the grain market, hybrid rye may become a strategic crop for food and feed security, as well as for the development of bioenergy. Its use opens up broad prospects for increasing the profitability of agricultural production due to stable yields and product quality, even under stressful growing conditions [4, 5].

To this end, starting in 2024, a comprehensive study was launched at the Levor Farm in the Berdychiv district of Zhytomyr region to investigate the productivity, growth and development characteristics, adaptive properties, and competitiveness of modern varieties and hybrids of winter rye grown using organic and traditional production methods (Fig. 1).

Figure 1. Comprehensive study of the formation of productivity
of modern varieties and hybrids of winter rye, 2025
(original photos)

In 2024, weather conditions in the Berdychiv district of Zhytomyr region were characterized by unstable temperatures and uneven distribution of precipitation, which significantly affected the growth and development of winter rye. The soils of the experimental plots are typical chernozems.

The experiment was conducted according to generally accepted field research methods using the systematic repetition method. The research design involved comparing modern varieties and hybrids of winter rye under the following conditions:

✓ traditional production (using mineral fertilizers and plant protection products);

✓ organic production (without the use of chemicals, with the application of organic fertilizers and adherence to the principles of ecological farming).

The size of the plot was 25 m², and the experiment was repeated four times. The variants were arranged sequentially.

During the study, the following were carried out:

✓ phenological observations – determination of the duration of growth and development phases;

✓ biometric measurements – plant height, number of stems, leaf index, ear parameters;

✓ phytosanitary monitoring – assessment of disease and pest infestation;

✓ agrochemical and soil analyses – nutrient content, acidity, soil structure;

✓ yield accounting – determination of grain weight from a plot with subsequent conversion to t/ha at standard moisture content.

Winter rye is notable for its exceptional ability to adapt to various soil and climatic conditions, which determines its stable productivity even under extreme environmental factors. The adaptive mechanisms of the crop include a complex of morphological, physiological, biochemical, and agroecological characteristics that make it competitive among cereal crops (Tables 1 and 2).

Table 1. The main adaptive mechanisms of winter rye

Group of mechanisms	Characteristics	Significance for plants
Morphological	Powerful root system capable of penetrating 1.5–2 m; high bushiness	Better use of moisture and nutrients.
Physiological	High photosynthetic activity in cool conditions; efficient use of moisture.	Drought resistance, efficient use of light.
Biochemical	Accumulation of soluble sugars in the tillering node.	Ensuring winter hardiness and energy reserves.
Adaptive-ecological	Tolerance to soil acidity, high competitiveness against weeds.	Ability to grow on poor and acidic soils.

Table 2. Comparative characteristics of the adaptive properties of winter rye and other cereal crops

Characteristic	Rye winter	Winter wheat	Spring barley
Winter hardiness	Very high	Medium–high	Low
Tolerance	High	Medium	Low
to soil acidity	Effective	Medium	High
Moisture utilization	High	Medium	Low

Hybrid winter rye has broad prospects for use thanks to its combination of high yield and adaptability to various agroecological conditions. In modern conditions, it is considered not only a traditional grain crop for bread and feed production, but also a strategic component of food and energy security. Thanks to its stable yield and grain quality even under stressful climatic conditions, rye can play a key role in the formation of a reserve grain fund.

The feed value of the crop is also important: green mass and straw are used in animal husbandry, and grain is used in the production of compound feed. Hybrid rye is also attracting attention as a raw material for bioenergy, as it is suitable for the production of bioethanol and biogas, which expands its uses in the transition to renewable energy.

The inclusion of winter rye in organic farming systems is promising due to its tolerance to soil acidity, low mineral nutrition requirements, and ability to suppress weeds. This makes the crop extremely important for environmentally balanced cultivation technologies. In addition, hybrid forms of rye show significant potential for increasing the profitability of agricultural production, as they allow for stable yields even in areas of risky farming.

Thus, the prospects for the use of winter hybrid rye cover the food, feed, energy, and environmental spheres, which determines its strategic role in the future of agricultural production in Ukraine and the world.

In summary, the results obtained emphasize the feasibility of wider introduction of hybrid winter rye into production practice using both traditional and organic technologies. In addition to its agronomic value, winter rye opens up opportunities in the food, feed, and energy sectors, contributing to the diversification of the agricultural sector and increasing its sustainability. Given the global challenges associated with climate change and the need for sustainable production, hybrid rye could become a strategic element of adaptive agriculture and economic security.

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