

RE-EVALUATION OF THE PRODUCTIVITY AND STABILITY OF WINTER BARLEY CULTIVAR “NEDA” ACROSS DIFFERENT ENVIRONMENTS

Silviya VASILEVA, (ORCID: 0000-0002-0781-1266)

*Agricultural University - Plovdiv, Faculty of Agronomy, Department of Crop Science,
12 Mendeleev Blvd, 4000 Plovdiv, Bulgaria
Corresponding author: silviya.valentinova@gmail.com*

Abstract. *The most effective way to ensure high yields and high-quality produce under intensive farming conditions is the crop variety. The selection and proper utilization of suitable cultivars are major factors for achieving high and stable yields. It is well known that cultivar performance is strongly influenced by environmental conditions, and no single variety can perform optimally across all regions. For this reason, all developed cultivars are subjected to official multi-location testing before their release, to evaluate their biological and economic characteristics under different agroecological conditions. Long-term cultivation may lead to changes in varietal performance due to environmental pressure, seed quality deterioration, or interactions with biotic and abiotic stress factors. Therefore, the re-assessment of existing cultivars under present-day conditions is necessary to determine their current suitability for agricultural practice. The current study aims to re-evaluate the stability, productivity, and adaptive response of the Bulgarian winter barley cultivar “Neda” based on historical (2010, 2011) and recent (2024, 2025) multi-environment trials. The results of the analyses conducted over various environmental conditions reveal that Neda clearly stands out as having a higher yield compared to the standard varieties (“Obzor”, “Emon,” and “Kaskadior 3” within the system of Executive Agency of Variety Testing, Field Inspection and Seed Control) and exhibits a high degree of adaptability to the environment and resilience to climatic fluctuations. Neda is a two-row barley variety owned by Agrodimex Ltd., characterized by high lodging resistance and very good winter hardiness. Grain protein content is around 12%, and the 1000-grain weight: 50-53 g. Hectoliter weight: 66 kg; yield: 693-801 kg/dka.*

Keywords: *barley, *Hordeum vulgare* L., Neda, plant breeding, re-evaluation, yield stability*

INTRODUCTION

The most effective factor in ensuring high yields and high-quality produce under intensive farming conditions is the crop variety (AHMAR ET AL., 2020). The diverse soil and climate regions of Bulgaria require a differentiated approach to crop cultivation technology (SEVOV AND GEORGIEVA, 2025). Conducting comparative trials in fields representative of the regions allows for the identification of the most promising varieties for each region and, on this basis, the establishment of an optimal variety structure for the country (RAJPUT, 2023; TODOROVSKA ET AL., 2018).

Despite global differences, the primary goal of breeding programs is to increase the yield levels of the developed varieties (ANAS, 2020), combined with enhanced adaptability to various growing conditions and grain quality tailored to the specific production sector. Before being introduced into production, new varieties must demonstrate their advantages in accordance with the regulations adopted in the country (KIM ET AL., 2024).

It is well known that there are no universal varieties (DIMOVA ET AL., 2024). Therefore, to achieve the maximum economic benefit from their introduction into production, varieties must be tested in the main production regions of the respective crops, and based on the data obtained, the most suitable regions for their distribution must be identified (CREISSEN ET AL., 2016). Newly developed varieties can replace previously regionalized and propagated varieties only if they demonstrate significant superiority in terms of yield and/or product

quality (KRISHNAN ET AL., 2021; LAWRENCE, 2025). When propagating the new varieties, agricultural techniques and methods are applied that ensure the production of seeds with high purity and quality. For example, negative selection, varietal and species cleaning, selection of large and uniform seeds, etc. Seed production crops undergo testing and seed inspection (GAO ET AL., 2025).

Bulgaria has a long tradition in plant breeding, with major contributions coming from the Agricultural Academy, the Bulgarian Academy of Sciences, and newer biotechnology centers. Key institutions include the Institute for Plant Genetic Resources “K. Malkov” in Sadovo, the Institute of Genetics “Acad. Doncho Kostoff,” AgroBioInstitute, the Institute of Agriculture in Karnobat, the Dobrudzha Agricultural Institute, the Maritsa Vegetable Crops Research Institute, and the Center of Plant Systems Biology and Biotechnology in Plovdiv (CPSBB). These institutions are especially active in cereal, vegetable, and germplasm-focused breeding, as well as in biotechnology-supported cultivar development (FAO, 2006; MIHOVA ET AL., 2018; GECHEV ET AL., 2023)

The varietal structure of cereal crops in Bulgaria shows marked differences among species. National breeding has a dominant role in barley and triticale, whereas wheat includes a substantial share of foreign cultivars, and rice remains highly dependent on external genetic resources. This pattern reflects the adaptive value of locally developed varieties, but it also highlights the need to preserve and expand domestic breeding capacity. In the context of climate variability and increasing production challenges, strengthening national breeding programs remains strategically important for ensuring long-term agroecological resilience and stable barley production amid climate variability (OSL, 2026).

MATERIAL AND METHODS

Field experiments were conducted during two experimental periods. The first period was within the official testing system of the Executive Agency for Variety Testing, Field Inspection and Seed Control (IASAS) in 2009 and 2011. The IASAS trials included six locations representing major agro-ecological zones in Bulgaria: Burgas, Radnevo, Chepintsi (Southern Bulgaria), and General Toshevo, Pordim, Selanovtsi (Northern Bulgaria).

The second stage was conducted under experimental conditions in 2024 and 2025 growing seasons at the Agricultural University of Plovdiv and the seed production fields of Agrodimex Ltd., Dragoevo (Shumen region).

Experimental conditions

The experimental sites covered a wide range of soil types, including leached and calcareous chernozems, alluvial-meadow soils, and grey forest soils. Soils in Northern Bulgaria were predominantly chernozemic with moderate humus content and good potassium supply but limited available phosphorus. The Plovdiv site was characterized by Mollic Fluvisols with favorable structure, moderate humus content (~3.7%), slightly alkaline pH, and good nutrient availability. The Dragoevo site was represented by grey forest soils with silty texture and high calcium content, influencing nutrient dynamics.

The climate is temperate and continental with Mediterranean influence during winter. Weather conditions during the study period were generally favorable for crop development. Winter temperatures occasionally decreased to -18°C, but no significant frost damage was observed. Rainfall distribution varied between years, with higher precipitation in autumn and late spring in some seasons, affecting sowing and harvesting conditions (Figure 1).

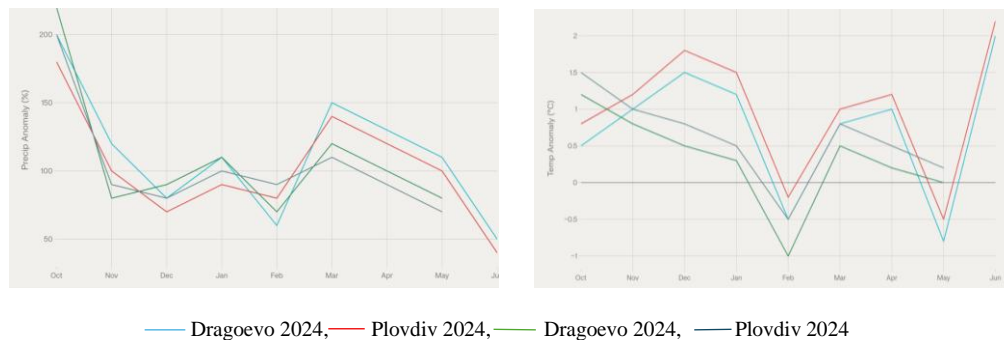


Figure 1. Average precipitation and temperatures for barley vegetation periods during the experiments

Experimental design and crop management

Field trials in Plovdiv and Dragoevo were conducted using a randomized block design with four replications and a plot size of 10 m². Sowing was performed within the optimal period (early to mid-October) at a seeding rate of 450 viable seeds m². Standard agronomic practices were applied during the growing season, including weed control according to infestation level.

Traits and data collection

The following traits were evaluated according to UPOV methodology (www.upov.int):

- grain yield (kg/dka, at 13% moisture)
- vegetation period and heading date
- thousand kernel weight (g)
- hectoliter weight (kg hl⁻¹)
- plant height and lodging resistance
- productive tillering (number of fertile stems m²)
- overwintering (%)

Disease resistance to *Pyrenophora teres*, *Erysiphe graminis f. sp. hordei*, *Rhynchosporium commune*, *Puccinia hordei*, and *Fusarium head blight* were assessed under natural infection conditions using standard scoring scales. In this scale values were 1 = resistant, 9 = highly susceptible.

Grain quality parameters, including extract content, protein content, and germination capacity, were determined in accredited laboratories.

Statistical analysis

Experimental data were processed using analysis of variance (ANOVA), and the significance of differences was determined using Duncan's multiple range test at $P \leq 0.05$.

RESULTS AND DISCUSSIONS

Variety "Neda" - breeding line 68903597
/Winter two-rowed, *Hordeum vulgare L. subsp. distichum (L.) Korn./*
(Figure 2)

ORIGIN: The variety was developed by sexual hybridization through crossing of Krazy 2 × Flaminco in 1987. It was grown in experimental plots (hybridization nursery) in 1988, in breeding nursery from 1989 to 1996, in control testing (1997), and evaluated in yield trials from 2000 to 2003.

AGRONOMIC CHARACTERISTICS: The variety was tested for biological and agronomic characteristics over a two-year period (2010 and 2011 growing seasons), using an average standard derived from the varieties “Obzor,” “Emon,” and “Kaskador 3”.

The average grain yield for the testing period was 691.3 kg/dka, compared to 650.3 kg/dka for the average standard.

In terms of the length of the growing season, the variety is on par with the average standard-217 days.

Plant density is 789 ear-bearing stems per m², compared to 841 for the average standard.

The weight of 1 000 seeds averaged over the trial period is 43.80 g, compared to 41.51 g for the average standard. The hectoliter weight is 66.1 kg, compared to 66.7 kg for the average standard.

Under natural infection conditions in the field, it is resistant to powdery mildew, moderately resistant to black rust, and susceptible to brown rust.

Under artificial infection conditions, it exhibited high resistance to powdery mildew and black rust and resistance to brown rust. It is comparable to the standard varieties in terms of resistance to *Fusarium* caused by *Fusarium culmorum*; it is resistant to *Fusarium graminearum* and *Fusarium oxysporum*.

The extract content is average, comparable to that of the standard varieties. The soluble nitrogen content is higher than that established for the standard varieties “Obzor,” “Kaskador 3,” and “Emon.” In terms of total protein content in the malt, the variety is on par with the standard varieties. The protein content averaged 12.4% on a dry matter basis across all testing sites during the trial period, compared to 12.5% on a dry matter basis for the average standard.

In order to be approved for commercial production, candidate varieties must undergo testing for distinctiveness, uniformity, and stability, and/or for biological and agronomic qualities specific to the country’s soil and climate regions, conducted by the agencies of the IASAS. The testing period lasts for at least two consecutive years.



Figure 2. Neda (<https://agrodimeks.com/>)

Neda demonstrated superior yield performance across IASAS historical trials and all four environment-year combinations in recent trials, achieving up to 18% compared to the average standard (Av. St.). Significantly outperforming it in Dragoevo (750-801 kg/dka) vs. Plovdiv (639-704 kg/dka), (Table 1). Neda maintained competitive crop density (785-801 stems/m² in Plovdiv, 811-930 in Dragoevo) comparable to standards, with excellent lodging resistance (score 9 across all sites/years), indicating strong culm stability under wet spring conditions prevalent in 2024-2025. Plant height remained moderate (84-97 cm), balancing yield potential with resistance to lodging (Table 2).

Table 1.

Grain yield obtained from variety trials of two-row winter barley during the 2024 and 2025 growing seasons, kg/dka.

Location/ year	Plovdiv 2023/2024			Dragoevo 2023/2024			Plovdiv 2024/2025			Dragoevo 2024/2025		
	kg/dka	GD	%	kg/dka	GD	%	kg/dka	GD	%	kg/dka	GD	%
Av. St	669		100	639		100,0	707,8		100,0	704		100
Obzor	726	+	109	656	-	103,1	701	-	97,54	651	000	92,2
Emon	624	o	93	601	-	94,09	741	-	103,3	748	+++	106
Kaskadior 3	656	-	98	654	-	102,8	712	-	99,16	704	-	101
Neda	693	-	104	750	+++	118	666	ooo	92,55	801	+++	116

GD	5%	43,29		6,69	36,8		5,98	24,34		3,50	6,11		1,19	13,7		2,01	13,44		2,04
GD	1%	58,29		9,01	49,6		8,06	32,80		4,71	8,23		1,61	18,4		2,70	18,09		2,75
GD	0.1%	77,29		12	65,7		10,68	43,46		6,25	10,9		2,13	24,4		3,58	23,99		3,64
Accuracy of the experiment, %			2,1			1,9			1,2			0,4			0,7				0,7

Table 2.

Assessment of crop density and lodging severity during the study period

Variety, year	Number of productive stems /m ² /		Stem height /cm/		Lodging* /score/	
	Plovdiv	Dragoevo	Plovdiv	Dragoevo	Plovdiv	Dragoevo
	2023-2024					
Obzor, 24	785	1100	100	98	8	9
Emon, 24	778	930	89	99	8	9
Kaskadior 3, 24	737	889	78	87	9	9
Neda, 24	785	930	84	88	9	9
	2024-2025					
Obzor, 25	797	811	102	97	8	9
Emon, 25	744	784	97	95	8	9
Kaskadior 3, 25	752	790	84	88	9	9
Neda, 25	801	817	97	90	9	9

* - Score 1: all plants are lodged; Score 2: More than 50% of the stems is touching the ground, with the exception of the top of the stalk, which is upright; Score 3-Less than 50% of the stems touches the ground, the rest is upright; Score 4-Stems are bent more than 60°, but do not touch the soil surface except at their base; Score 5-Stems are bent between 45° and 60°; Score 6-Stems are tilted between 30-45°; Score 7-Stems are tilted between 15-30°; Score 8-Stems are slightly tilted (<15°); Score 9-Stems are upright, vertical

Neda's brewing quality parameters were competitive, with superior 1000-grain weight (50.2-52.8 g, highest alongside Obzor) and acceptable uniformity (96.3-94.5% Class 1), though extract content was lowest (70.5-78.5%). Compared to standards, Neda offers balanced physical quality suitable for brewing, with heavier kernels compensating for moderate extract potential (Table 3). Neda recorded the lowest nitrogen (1.68-1.89%) and grain protein (10.5-11.79%) levels, potentially advantageous for malting (reduced modification risk) but lower than standards (12.5-16.88%). Carbon content was consistent across varieties (~44-45%). This profile suggests Neda produces high-yield, low-protein grain ideal for brewing under intensive management, though producers targeting feed markets may prefer higher-protein standards like Obzor (Table 4).

Table 3.

Average data on the brewing qualities of the genotypes studied during the study period

Variety	Weight of 1,000 grains/g/		Uniformity: Class 1		Extract %/		Moisture %/		Germination %/	
	Plovdiv v	Dragoevo vo	Plovdiv v	Dragoevo vo	Plovdiv v	Dragoevo vo	Plovdiv v	Dragoevo vo	Plovdiv v	Dragoevo vo
Obzor	50.5	52.0	98.4	99.1	76.6	78.0	12.1	12.3	92	93
Emon	49.5	51.8	99.8	89.3	75.9	77.5	12.3	12.2	94	92
Kaskadi or 3	46.7	48.9	96.7	92.2	76.1	78.2	12.1	12.8	92	90
Neda	50.2	52.8	96.3	94.5	70.5	78.5	12.1	12.3	90	92

Table 4.

Nitrogen, carbon, and crude protein content (%), average for the 2024, 2025 period

Variety	nitrogen %/		carbon %/		grain protein %/	
	Plovdiv	Dragoevo	Plovdiv	Dragoevo	Plovdiv	Dragoevo
Obzor	2.70	2.05	44.72	45.33	16.88	12.8
Emon	2.45	1.90	44.29	44.98	15.30	11.7
Kaskadi or 3	2.00	2.00	44.41	45.01	12.51	12.5
Neda	1.89	1.68	44.28	44.87	11.79	10.5

The most economically important diseases in barley (*Hordeum vulgare*) production systems include net blotch caused by *Pyrenophora teres*, powdery mildew (*Erysiphe graminis f. sp. hordei*), scald (*Rhynchosporium commune*), rusts (*Puccinia hordei*), and Fusarium head blight (*Fusarium spp.*), due to their widespread occurrence and significant impact on yield and grain quality. Under the conditions of the present study, the cultivar Neda exhibited differential disease response, characterized by susceptibility to net blotch and moderate response to powdery mildew, while no symptoms of other major pathogens were observed. Based on the applied 1-9 scoring scale (1 = resistant, 9 = highly susceptible), Neda can be classified with an estimated score of 8 for net blotch and 5-6 for powdery mildew, indicating a need for targeted management under conducive environmental conditions.

Recommendations to Producers

Prioritize Neda for malting/brewing: Its high yield, disease resistance, and quality (extract 70.5-78.5%, germination 90-92%) make it ideal for northern/southern Bulgarian regions, especially under variable climate (wet springs, hot summers).

Sowing and management: Use 450 seeds/m² in early-mid October; apply P pre-sowing (6 kg/dka) and N top-dress; monitor lodging in wet springs (expect score 9 resilience).

Regional fit: Excellent for Dragoevo (higher yields 750-801 kg/dka) and Plovdiv; replace aging standards where yield superiority >10% is evident.

Seed production: Employ negative selection and roguing for purity.

CONCLUSIONS

The re-evaluation trials confirm that winter barley cultivar "Neda" maintains superior productivity and environmental adaptability across historical (2010, 2011 by IASAS) and recent (2024, 2025) conditions in Plovdiv and Dragoevo, outperforming standards ("Obzor," "Emon," and "Kaskadior 3") in yield (e.g., 750-801 kg/dka vs. 639-704 kg/dka average; 4-18% relative) despite climate variability. Neda exhibits high stability, with consistent performance under warmer/wetter recent years (e.g., record 2024 heat, excessive fall rain), good overwintering, lodging resistance (score 9), and disease tolerance (powdery mildew 5-6, no infection by rust pathogens was observed). Quality traits remain reliable (1000-grain weight 50.2-52.8 g, hectoliter weight ~66 kg, protein ~10.5-12.4%), though slightly lower protein in recent trials suggests minor environmental influence. Multi-environment analysis reveals low genotype × environment interaction for Neda, positioning it as broadly adapted.

BIBLIOGRAPHY

- AHMAR, S., GILL, R. A., JUNG, K. H., FAHEEM, A., QASIM, M. U., MUBEEN, M., ZHOU, W., 2020 - Conventional and Molecular Techniques from Simple Breeding to Speed Breeding in Crop Plants: Recent Advances and Future Outlook. *Int. J. Mol. Sci.* 21, 2590. <https://doi.org/10.3390/ijms21072590>
- ANAS, M., 2020 - Inheritance of grain yield and grain yield components in barle. <https://doi.org/10.13140/RG.2.2.31859.96807>
- CREISSEN, H.E., JORGENSEN, T.H., BROWN, J.K.M., 2016 - Increased yield stability of field-grown winter barley (*Hordeum vulgare* L.) varietal mixtures through ecological processes. *Crop Prot. Guildf. Surrey* 85, 1-8. <https://doi.org/10.1016/j.cropro.2016.03.001>
- DIMOVA, D., GOICHEVA, M., Institute of Agriculture-Karnobat, Agricultural Academy, Bulgaria, 2024 - Agrobiological characteristics and productive capabilities of spring barley accessions. *Agric. Sci.* 16, 41-48. <https://doi.org/10.22620/agrisci.2024.43.004>
- GAO, S., HE, P., GONG, X., LI, H., LIU, Y., WANG, Q., WANG, X., HE, A., FU, Y., 2025 - Sensitivity and uncertainty analysis of wheat cultivar parameters of the DSSAT model under different water and N treatments. *Sci. Rep.* 15, 10441. <https://doi.org/10.1038/s41598-025-95260-y>
- GECHEV, T., KAZAKOV, P., IVANOVA, A., IVANOVA, T., MIRCHEVA, M., KOLEV, V., GANEVA, D., TABAKOVA-KOMSALOVA, V., RUSEVA, M., KANTARDJIEVA, E., KAZASHKA, V.S., 2023 - Establishment and development of the Center of Plant Systems Biology and Biotechnology in Plovdiv, Bulgaria. *Open Res. Eur.* 3, 140. <https://doi.org/10.12688/openreseurope.16514.3>
- KIM, S.-H., CHOI, I., KIM, J. B., 2024 - Advancing Plant Breeding with Next-Generation Technologies: Insights from Recent Research. *Plants* 13, 2877. <https://doi.org/10.3390/plants13202877>
- KRISHNAN, P., MAITY, P.P., KUNDU, M., 2021 - Sensitivity analysis of cultivar parameters to simulate wheat crop growth and yield under moisture and temperature stress conditions. *Heliyon* 7, e07602. <https://doi.org/10.1016/j.heliyon.2021.e07602>
- LAWRENCE, R., 2025 - Four new varieties added to Spring Barley Recommended List. *News AA Farmer*. URL <https://www.aafarmer.co.uk/crops/four-new-varieties-added-to-spring-barley-recommended-list.html> (accessed 5.1.26).

- MIHOVA, G., BAYCHEV, V., ALEXANDROV, T., PETROVA, T., STANOEVA, Y., IVANOVA, V., 2018 Breeding of cereal crops at dobrudzha agricultural institute - general toshevo, bulgaria. J. Agric. Food Environ. Sci. JAFES 72, 124-131.
- RAJPUT, S., 2023 - Advancements in Plant Breeding: Pioneering Sustainable Agriculture 6, 85-87. [https://doi.org/10.37532/%20jagri.2023.6\(3\).85-87](https://doi.org/10.37532/%20jagri.2023.6(3).85-87)
- SEVOV, A., GEORGIEVA, V., 2025 - Adaptation of spring field crop technology to changing climate conditions lxxviii, 711-717.
- TODOROVSKA, E., MHADI, N.A., CHRISTOV, N., BOZHANOVA, V., ATANASSOV, A., 2018 - Cereal genetics and genomics in Bulgaria - challenges and perspectives, 71.
- FAO - Food and Agriculture Organization, 2006 - Information by Dr. Georgina Kosturkov, Bulgaria's full report from the PBBC survey. Last revised 10-03-2010
<https://www.fao.org/in-action/plant-breeding/nospartenaires/europe/bulgaria/fr/>
- IASAS - Executive Agency of Variety Testing, Field Inspection and Seed Control (<https://iasas.government.bg/>)
- OSL, 2026 - Official variety list of varieties of agricultural and vegetable plant species accepted for certification and marketing on the territory of the republic of bulgaria 2026, <https://iasas.government.bg/att/OSL%201%20-%202026%206.pdf>
- UPOV - Union for the Protection of New Varieties (<https://www.upov.int/en/web/upov>)