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CULTIVATION OF TWO-ROW BARLEY VARIETIES IN NĂDLAC, ARAD COUNTY

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Abstract: *The present study evaluates the agronomic and grain-quality performance of two-row barley under the pedoclimatic conditions of Nădlac, Arad County, during the 2025–2026 agricultural year. The available farm records comprised three crop variants: STING established in autumn, FLAVIA established in autumn, and STING established in spring. STING is commercially described by the breeder as a spring malting barley; consequently, its autumn-established record is treated here strictly as a non-standard farm observation and not as a breeder-recommended sowing practice. The assessment focused on grain yield, harvest moisture, protein concentration and hectoliter mass. The crop-management section for 2025–2026 was prepared by calendar-aligning the operation sequence and nominal input rates from the 2022–2023 farm barley technology sheet; historical input prices were excluded. The highest recorded yield was obtained by autumn-established STING, with 5.87 t ha^{-1}, compared with 4.30 t ha^{-1} for autumn FLAVIA and 4.59 t ha^{-1} for spring STING. Grain moisture was 11.2% for both autumn records and 9.9% for spring STING. Protein concentration ranged from 12.3% in autumn-established STING to 14.8% in spring STING, while hectoliter mass ranged from 60.8 to 66.3 kg hl^{-1}. Autumn-established STING exceeded the study mean yield by 19.3% and combined the highest productivity with the highest hectoliter mass. In contrast, spring STING showed the highest protein concentration but the lowest hectoliter mass. Because the dataset contains one aggregated farm value per variant, without replicated plots, the results are descriptive and cannot separate genotype, sowing season, environment and management effects. The study therefore provides a local comparative case assessment and identifies priorities for replicated multi-year trials, particularly standardized sowing-date comparisons, nitrogen management and direct malting-quality measurements.*

Keywords: *two-row barley, winter barley, spring barley, grain yield, protein, hectoliter mass, Nădlac*

INTRODUCTION

Barley (*Hordeum vulgare L.*) is one of the major temperate cereals and remains strategically important because the crop combines comparatively high ecological plasticity with multiple end uses, including feed, food, malt and brewing. For malting and brewing, the economic value of the crop depends not only on grain yield but also on a relatively narrow set of quality attributes, particularly protein concentration, grain size, kernel uniformity and grain density. The simultaneous achievement of high productivity and adequate technological quality is therefore a central objective in cultivar selection and crop management (HU et al., 2021; KUMAR et al., 2022).

Genotype, environment and crop management jointly determine barley performance. Multi-environment studies have repeatedly shown that yield, test weight and protein concentration are sensitive to genotype × environment interactions, while the same genotype may express contrasting quality profiles when exposed to different water, thermal or nitrogen regimes (HALSTEAD et al., 2023; KUNZE et al., 2024; BRATKOVIĆ et al., 2024). These interactions are particularly relevant in regions where spring rainfall is irregular and temperature can increase rapidly during grain filling, because high temperature and water limitation can shorten the grain-

filling period, reduce kernel mass and modify grain protein concentration (OTERO et al., 2021; REZAEI et al., 2022).

Nitrogen management is one of the most influential technological factors in malting barley. Nitrogen can increase biomass and yield when soil water supply allows efficient uptake, but excessive or poorly timed nitrogen may increase grain protein beyond the range required for malt production. Long-term and controlled studies have shown that yield response to nitrogen is strongly environment-dependent and that newer cultivars can differ substantially in nitrogen-use efficiency (SIELING and KAGE, 2022; CAMMARANO et al., 2024). From a sustainability perspective, nitrogen management must therefore be optimized rather than maximized, because both economic efficiency and malt quality can decline when the protein–yield balance is displaced (VAHAMIDIS et al., 2023).

The Western Plain of Romania provides favorable conditions for cereal production but is increasingly exposed to high interannual variability in precipitation and temperature. Recent Romanian research has confirmed significant varietal differences in yield, protein concentration and hectoliter mass, emphasizing the importance of testing commercial genotypes under local conditions rather than extrapolating performance from other agroecological regions (AUNGURENCEI et al., 2025). Nădlac, situated in western Arad County near the Mureș River and the Romanian–Hungarian border, belongs to the lowland sector of the Western Plain. Earlier regional studies describe extensive arable agriculture and the presence of naturally fertile chernozem soils in the locality, conditions that support intensive cereal production (FLORESCU et al., 2015).

Two-row barley is of particular interest for quality-oriented production. The commercial cultivar FLAVIA is described by the breeder as a two-row winter barley with high productive potential, good winter hardiness and tolerance to drought and heat. STING is described as a spring malting barley with low beta-glucan content and technological attributes favorable for malt extract (SAATEN-UNION ROMANIA, 2026a; SAATEN-UNION ROMANIA, 2026b). The farm dataset also contains an autumn-established STING observation. Because this establishment timing does not correspond to the cultivar's standard commercial classification as spring barley, it is retained only as a documented local farm observation and should not be interpreted as evidence of a recommended autumn sowing practice.

The objective of this study was to evaluate, under the commercial production conditions of Nădlac, the recorded grain yield and selected grain-quality indicators of three barley variants: STING autumn, FLAVIA autumn and STING spring. A secondary objective was to interpret the local results in relation to current scientific evidence on genotype × environment interaction, nitrogen management and grain quality. Because the available dataset contains aggregated farm values rather than replicated plot observations, the analysis is intentionally descriptive and no statistical significance is attributed to the observed differences.

MATERIAL AND METHODS

Study area. The assessment was conducted in the agricultural perimeter of Nădlac, Arad County, western Romania, during the 2025–2026 agricultural year. Nădlac is located in the western sector of the Romanian Western Plain, close to the Mureș River. The locality is characterized by a predominantly arable land use and by soil resources that include typical, cambic, argic and alkaline chernozems with generally good natural fertility (FLORESCU et al., 2015). For the wider Arad lowland, the climate is temperate-continental with western influences, warm summers, cold winters interrupted by warming periods, and an annual precipitation regime

that is variable in both amount and distribution. These regional characteristics provide a suitable but climatically variable environment for autumn and spring cereals.

Climatic context, 2025–2026. The climatic interpretation was based on the monthly climatological assessments issued by the Romanian National Meteorological Administration (ANM) for Crișana and western Romania, supplemented by values reported for stations in Arad County. Because the public ANM summaries do not provide a dedicated Nădlac station series, these data are used as regional agroclimatic context rather than as direct plot-level meteorological measurements. September 2025 was unusually warm at national scale, with a mean anomaly of +2.6 °C relative to the 1991–2020 median; mean monthly temperatures above 20 °C occurred in parts of western Crișana, and the station at Șiria (Arad County) recorded a minimum temperature of 23.0 °C on 5 September. In October, the precipitation regime became deficient over most of Crișana, while Chișineu-Criș recorded a precipitation anomaly of −71.1%, indicating a potentially restrictive moisture environment during autumn establishment and tillering (ANM, 2025).

Winter and spring conditions were strongly variable. December 2025 was warm (+2.4 °C at national scale) and exceptionally dry, with mean precipitation 76.9% below the 1991–2020 median. January 2026 then brought approximately 40–75 mm over Crișana and a generally very to extremely wet regional regime, providing partial winter water recharge, while February remained warm in western Romania and mostly normal in precipitation. The most agronomically relevant moisture deficit developed in March and April: March precipitation fell below 10 mm, locally below 5 mm, in western Romania, and April was very to extremely dry across Crișana; at Chișineu-Criș the precipitation anomaly reached −96.4% (ANM, 2026). This sequence coincided with spring regrowth, stem elongation and heading of autumn barley and with establishment and early development of spring barley.

Late spring and early summer maintained a substantial stress risk. May 2026 was close to the national thermal normal, but precipitation anomalies remained predominantly negative in Crișana. June became warm to very warm in western Romania, with monthly mean temperatures of 22–24 °C across much of the west. The Arad meteorological station reached 40.2 °C on 29 June, exceeding its previous June station maximum, while rainfall deficits persisted in the western part of the country; Chișineu-Criș recorded a June precipitation anomaly of −66.9% (ANM, 2026). The late-June extreme documents the high thermal-stress potential of the region, although its direct influence on the measured lots cannot be assumed because exact plot harvest dates were not available and some autumn barley may already have been harvested.

Biological material. Three farm-recorded variants were included: STING established in autumn, FLAVIA established in autumn and STING established in spring. Both cultivars are supplied by SAATEN-UNION. FLAVIA is a two-row winter barley cultivar recommended for winter-barley areas and characterized by high tillering capacity and good tolerance to foliar and ear diseases. STING is commercially classified as a spring malting barley, and the breeder recommends balanced fertilization so that grain protein remains within the technological target for brewing use (SAATEN-UNION ROMANIA, 2026a; SAATEN-UNION ROMANIA, 2026b). Accordingly, the autumn-established STING variant is reported as a farm observation outside the cultivar's standard spring classification; the present dataset does not establish the agronomic suitability of autumn sowing for STING.

Crop-management technology, 2025–2026. The technological presentation for the 2025–2026 agricultural year was developed from the farm barley operation sheet recorded for 2022–2023, used as the operational model requested for the present study. The sequence of field operations and the nominal input rates were retained and the calendar was aligned to the 2025–

2026 crop cycle. Historical prices and cost values were deliberately excluded because they belong to the 2022–2023 economic context and are not required for the agronomic comparison. The resulting sequence comprises primary tillage and seedbed preparation, basal NPK fertilization, sowing and rolling, an autumn plant-protection intervention, spring top-dressing, three staged spring crop-protection/nutrition interventions and harvest (Table 2).

Traceability of the technological data. The operation sheet used as the model is an autumn-barley record; consequently, Table 2 most directly describes the farm-management framework applied to the autumn-established records. It should not be read as a breeder recommendation for autumn sowing of STING, which is commercially classified as a spring malting barley. The 2025–2026 production sheet does not contain a separate complete operation ledger for spring-established STING. For this reason, the exact spring sowing date and all spring-STING-specific input applications are not presented as independently verified field records. This distinction is maintained so that the comparison of yield and quality remains transparent and does not attribute unverified management details to the spring crop.

Recorded variables. Four indicators were available for each variant: grain yield (kg ha^{-1}), grain moisture at evaluation (%), grain protein concentration (%) and hectoliter mass (kg hl^{-1}). Grain yield was additionally expressed in t ha^{-1}. Hectoliter mass was interpreted as a physical quality indicator reflecting bulk density and kernel filling, while protein concentration was discussed in relation to the technological requirements of malting barley. No additional laboratory indicators such as thousand-kernel weight, grain calibration, germination energy, beta-glucan or malt extract were available in the current dataset.

Data analysis. The source records contain one aggregated value per commercial variant and do not document replicated experimental plots. For this reason, the analysis was limited to descriptive statistics. The arithmetic mean across the three variants was calculated for each indicator, and each variant was expressed relative to the study mean. Pairwise percentage differences were used only to describe the magnitude of contrasts. No ANOVA, LSD test, correlation significance test or genotype × environment model was applied because the available sample size and experimental structure would not support valid inferential statistics.

Table 1

Biological material and establishment season used in the Nădlac assessment

Variant	Cultivar	Establishment season	Commercial characterization
V1	STING	Autumn (farm record)	Non-standard farm observation; STING is commercially classified as spring malting barley
V2	FLAVIA	Autumn	Two-row winter barley; high productive potential
V3	STING	Spring	Spring malting barley; breeder-aligned establishment season

Table 2

Autumn-barley crop-management sequence presented for the 2025–2026 agricultural year, calendar-aligned from the farm 2022–2023 technology model

Crop phase / date	Operation	Input / product	Rate per ha	Agronomic role
23 Sep 2025	Primary tillage	Ploughing for sowing	1 pass	Soil loosening and incorporation of residues
26 Sep 2025	Basal fertilization	NPK 16-16-16	200 kg ha^{-1}	Basal N, P and K supply before sowing

Crop phase / date	Operation	Input / product	Rate per ha	Agronomic role
27 Sep 2025	Seedbed preparation	Disc harrowing	2 passes	Seedbed refinement and leveling
29 Sep 2025	Establishment	Treated barley seed; sowing + rolling	280 kg seed ha^{-1}	Crop establishment and seed–soil contact
31 Oct 2025	Autumn crop protection	Zizan + Cyperguard	0.30 + 0.06 L ha^{-1}	Autumn protection according to the farm technology model
28 Feb 2026	Spring top-dressing	Elixir Zorca (as recorded)	156 kg ha^{-1}	Early spring nutrient supply
20 Mar 2026	Spring treatment I	Moxa	0.40 L ha^{-1}	First spring protection treatment
30 Mar 2026	Spring treatment II	Falcon + Trimeo + Flurostar + Aminoplant	0.70 + 0.10 + 0.50 + 1.00 L ha^{-1}	Combined crop protection and foliar support
28 Apr 2026	Spring treatment III	Globaztar + Fezan + Sumi Alpha + liquid N	0.70 + 0.50 + 0.20 + 5.00 L ha^{-1}	Late crop protection and foliar N supply
20 Jun 2026	Harvest	Mechanical harvest and transport	—	Grain recovery at technological maturity

The technological calendar indicates a conventional intensive sequence in which the crop receives basal compound fertilization before sowing and an additional spring nutrient input, followed by staged plant-protection interventions. The management logic is consistent with the requirements of autumn barley in the Western Plain: establishment is completed at the end of September, crop protection begins in autumn, and spring inputs are distributed across the period of renewed vegetative growth and reproductive development. Because the source model is a farm operational sheet rather than a replicated experimental protocol, the technology is reported descriptively and is not treated as an experimental factor in the statistical interpretation.

RESULTS AND DISCUSSION

The three farm-recorded variants showed clear descriptive differences in productivity and grain quality (Table 3). The mean yield of the dataset was 4.92 t ha^{-1}. Autumn-established STING produced 5.87 t ha^{-1}, which was 0.95 t ha^{-1} above the study mean (+19.3%). FLAVIA established in autumn produced 4.30 t ha^{-1}, or 12.6% below the study mean, while spring-established STING reached 4.59 t ha^{-1}, corresponding to 6.7% below the mean. Pairwise, the autumn-established STING record was 36.5% higher than FLAVIA autumn and 27.9% higher than STING spring. These contrasts are practically relevant within the available records, but they cannot be interpreted as independent cultivar or sowing-date effects because the observations were not generated in a replicated, controlled sowing-date experiment.

The observed yield pattern is consistent with the general agronomic advantage that autumn-established barley can obtain from a longer vegetative period, earlier canopy development and a greater opportunity to exploit winter–spring soil water. However, the magnitude of this advantage is highly environment-dependent. Studies across contrasting locations show that barley yield is strongly conditioned by seasonal rainfall distribution, maximum temperature during reproductive development and genotype-specific responses to those variables (BRATKOVIĆ et al., 2024; DE SANTIS and CAMMARANO, 2024). Likewise, stress experiments demonstrate that drought and heat can reduce spike fertility, grain number and grain

weight, making local adaptation a central component of cultivar performance (ABDELGHANY et al., 2024).

The 2025–2026 climatic sequence provides an important contextual framework for interpreting the farm records. The autumn-established crops had a longer period for root and canopy development before spring and could potentially benefit from the January moisture recharge, whereas spring STING developed during the pronounced March–April moisture deficit documented for western Romania. This seasonal contrast is agronomically compatible with the lower hectoliter mass and higher grain protein recorded for spring STING, because water limitation can restrict kernel filling and increase the relative concentration of grain nitrogen. However, this remains a plausible interpretation rather than demonstrated causality, since plot-level soil-water measurements, phenological observations and a dedicated Nădlac meteorological series were unavailable. The 40.2 °C maximum registered at Arad on 29 June 2026 documents regional thermal-stress potential, but it should not be assigned directly to the measured grain differences because the exact harvest date of each lot was not independently verified (ANM, 2026; OTERO et al., 2021; REZAEI et al., 2022).

Table 3

Grain yield and quality indicators recorded for the three barley variants in Nădlac, 2025–2026

Variant	Yield (kg ha^{-1})	Yield (t ha^{-1})	Moisture (%)	Protein (%)	Hectoliter mass (kg hl^{-1})
STING autumn-established	5 870	5.87	11.2	12.3	66.3
FLAVIA autumn-established	4 300	4.30	11.2	12.7	65.5
STING spring-established	4 590	4.59	9.9	14.8	60.8
Study mean	4920	4.92	10.77	13.27	64.2

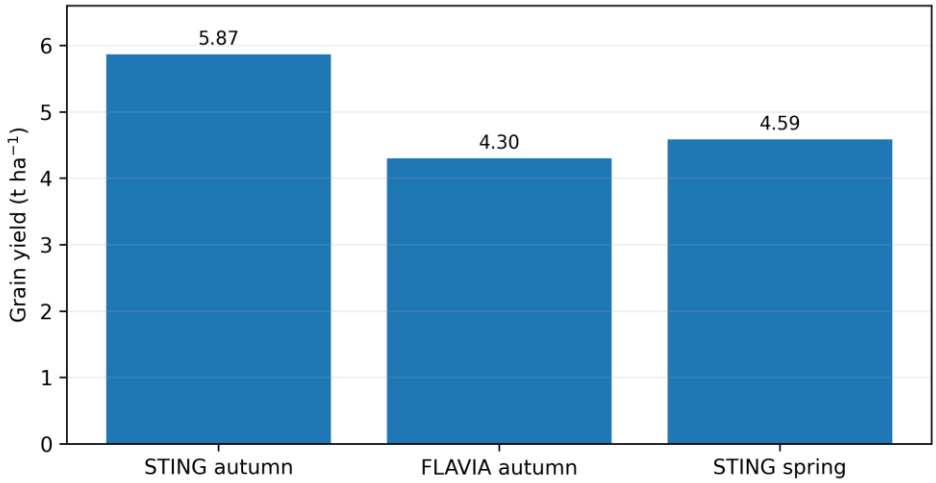


Figure 1. Grain yield of the barley variants evaluated in Nădlac during the 2025–2026 agricultural year.

Grain moisture at evaluation was identical for the two autumn variants (11.2%) and lower for spring STING (9.9%). The difference of 1.3 percentage points indicates that the spring

variant was drier at the moment of quality determination. Moisture affects harvest timing, storage safety and the basis on which commercial quality is interpreted, but the available records do not specify whether yields were standardized to a common moisture content. Consequently, the yield comparison is reported exactly as recorded in the farm dataset and should not be treated as a moisture-corrected comparison.

Protein concentration presented the opposite pattern to yield. Autumn STING had the lowest protein value, 12.3%, followed by FLAVIA autumn with 12.7%, whereas spring STING reached 14.8%. The dataset mean was 13.27%, and spring STING exceeded this mean by 11.6%. The difference between spring and autumn STING was 2.5 percentage points, equivalent to a relative increase of approximately 20.3%. This contrast is agronomically important because grain protein is one of the major determinants of malting acceptance and malt performance. Studies have demonstrated that protein is influenced simultaneously by genotype, environment and nitrogen management and can become the principal driver of variation in malting-quality indices (HALSTEAD et al., 2023).

For brewing-oriented barley, excessively high grain protein can reduce the proportion of starch available for malt extract and can modify malt friability and processing behavior. The official technical description of STING recommends balanced fertilization adapted to soil fertility and pedoclimatic conditions so that the admitted optimum protein content does not exceed approximately 10–11% (SAATEN-UNION ROMANIA, 2026b). In the Nădlac records, both STING observations exceeded that producer target, particularly the spring-established crop. The interpretation must remain end-use specific because acceptance limits can vary among maltsters and products. The practical implication is that nitrogen rate and timing should be calibrated against both yield and grain-protein response rather than optimized for yield alone (CAMMARANO et al., 2024; VAHAMIDIS et al., 2023).

Hectoliter mass averaged 64.2 kg hl^{-1} across the three observations. Autumn STING recorded 66.3 kg hl^{-1}, FLAVIA autumn 65.5 kg hl^{-1} and spring STING 60.8 kg hl^{-1}. Thus, the two autumn variants were 3.3% and 2.0% above the study mean, respectively, whereas spring STING was 5.3% below it. Hectoliter mass is a useful physical indicator because it integrates aspects of kernel filling, density and uniformity, although it cannot replace direct malting-quality measurements. Recent barley studies similarly show that hectoliter weight and other physical grain traits vary with genotype and environmental conditions and can contribute to quality discrimination among cultivars (AUNGURENCEI et al., 2025; RANI et al., 2024).

The combined quality profile indicates that autumn STING expressed the highest yield and hectoliter mass while maintaining the lowest protein concentration of the three variants. FLAVIA autumn had a lower yield but maintained a hectoliter mass close to that of autumn STING and an intermediate protein concentration. Spring STING combined intermediate yield with the highest protein and the lowest hectoliter mass. When the indicators are standardized to the dataset mean (Figure 2), the trade-off becomes evident: the spring variant is above average for protein but below average for yield and grain density, whereas autumn STING is above average for yield and hectoliter mass but below average for protein. This pattern is descriptive and should not be generalized beyond the field records evaluated here.

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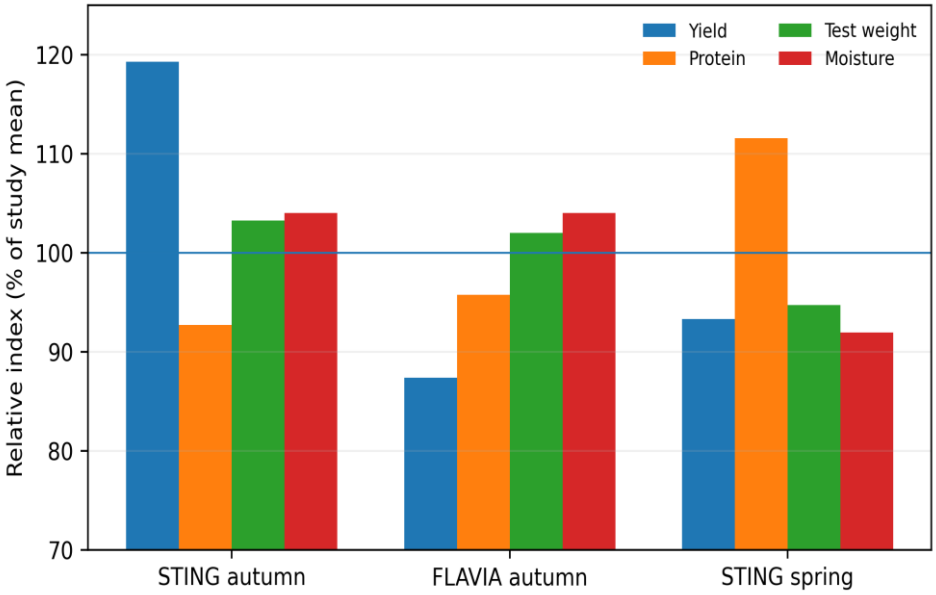


Figure 2. Relative performance of yield and grain-quality indicators; 100 represents the mean of the three variants.

Table 4

Relative deviations from the mean of the three evaluated variants

Variant	Yield index (%)	Protein index (%)	Hectoliter mass index (%)	Moisture index (%)
STING autumn-established	119.3	92.7	103.3	104.0
FLAVIA autumn-established	87.4	95.7	102.0	104.0
STING spring-established	93.3	111.6	94.7	92.0

The present results underline the need to separate cultivar effects from sowing-season effects in future experimentation. STING appears in both autumn and spring farm records, but this comparison is not a controlled sowing-date experiment, and the breeder classifies STING as a spring malting cultivar. The autumn technological framework is documented through the calendar-aligned farm model, whereas a complete independent operation ledger for spring STING is not available; plot replication, soil water at establishment and phenological measurements are also undocumented. A future trial should compare predefined sowing dates under a common factorial management structure and replicated plots, preferably across at least two or three agricultural years. Such a design would support analysis of variance and would clarify whether the observed yield and protein contrasts represent stable responses or season-specific farm outcomes.

From a quality perspective, future work should add thousand-kernel weight, grain calibration above 2.5 and 2.8 mm, germination energy, beta-glucan, starch and malt extract. Malting quality is multivariate: protein concentration alone cannot define final industrial

suitability, and physical traits such as grain size and test weight interact with biochemical properties during malting (OTERO et al., 2021; KUMAR et al., 2022; RANI et al., 2024). The inclusion of these parameters would enable a more rigorous comparison between FLAVIA and STING and would align the field assessment more closely with the requirements of the malting and brewing industries.

Overall, the Nădlac observations fit the broader scientific evidence that barley performance must be evaluated locally. Grain yield and quality are not fixed varietal properties; they are expressions of genetic potential under a specific combination of sowing season, soil, weather and crop management. The value of the present case study lies in documenting a clear local performance contrast and in defining the variables that should be controlled in the next experimental cycle.

CONCLUSIONS

Under the commercial conditions recorded in Nădlac during the 2025–2026 agricultural year, the autumn-established STING observation achieved the highest grain yield, 5.87 t ha^{-1}, and the highest hectoliter mass, 66.3 kg hl^{-1}. Its protein concentration was 12.3%, the lowest value among the three records but still above the producer guidance associated with STING for malting use. FLAVIA established in autumn produced 4.30 t ha^{-1}, with 12.7% protein and a hectoliter mass of 65.5 kg hl^{-1}. Because STING is commercially classified as spring malting barley, the autumn record must be interpreted as a non-standard local farm observation rather than as a validated recommendation for autumn sowing.

Spring-established STING produced 4.59 t ha^{-1} and had the lowest grain moisture at evaluation, 9.9%, but it also showed the highest protein concentration, 14.8%, and the lowest hectoliter mass, 60.8 kg hl^{-1}. The three farm records therefore show a descriptive contrast between productivity and the protein/density profile, but the available dataset does not permit causal attribution to genotype or sowing season.

For practical crop management, the data support closer adjustment of nitrogen supply to the intended end use, particularly where barley is targeted for malt. A higher protein concentration should not be interpreted automatically as superior quality because malting specifications require a balance between protein, starch, grain size and germination characteristics. The 2025–2026 records should therefore be complemented by direct malting-quality measurements.

The 2025–2026 technological presentation follows the farm operation sequence documented in the 2022–2023 autumn-barley model: soil preparation and sowing in autumn, 200 kg ha^{-1} NPK 16-16-16 as basal fertilization, an early spring top-dressing, staged crop-protection interventions through April and harvest in June. This sequence provides a documented management framework for the autumn-established records; it does not constitute a breeder-endorsed autumn technology for STING. The spring STING technology should be recorded separately and completely in subsequent experimental cycles.

The present dataset is descriptive and contains one aggregated observation per variant. A definitive varietal or sowing-season recommendation requires replicated field trials across several agricultural years, with uniform management and documented soil and climatic conditions. Future experiments should retain FLAVIA and STING, but should test sowing season only within a controlled design that respects cultivar-specific commercial recommendations and clearly identifies any deliberately non-standard treatment. Nitrogen rate, grain calibration and direct malting-quality traits should also be included. The marked March–

April moisture deficit and the warm-to-very-warm conditions documented in western Romania during the crop cycle should be treated as environmental covariates in subsequent trials.

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