15th INTERNATIONAL CONFERENCE OF ECOSYSTEMS (ICE2025)
June 6-8, 2025, Chicago, Illinois, USA (online)
https://sites.google.com/view/15th-inter-conf-of-ecosystems/home

EVALUATION OF WHEAT CULTIVARS AND FERTILIZATION STRATEGIES FOR SUSTAINABLE BAKING PRODUCTION IN KOSOVO

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Abstract

Sustainable wheat production is essential for food security and environmental conservation in Kosovo's baking industry. This study investigated the agronomic performance and grain quality of three wheat cultivars (Andalusia, Adelaide, Antille) under different diammonium phosphate (DAP) fertilization regimes (50%, 100%, 150% of recommended rates) across two distinct agroecological zones (Cërkulez and Gusar). Using a two-factorial randomized complete block design with three replications, we measured phenological development, yield components, and grain quality parameters. Results demonstrated significant ($p<0.05$) cultivar × fertilization interactions, with Antille showing superior yield (5.2 t/ha) and protein content (13.0%) at 100% DAP, while Adelaide exhibited better nitrogen use efficiency at lower fertilization levels. The 100% DAP application (200-230 kg/ha) optimized both yield and grain quality without excessive nutrient input. These findings provide evidence-based recommendations for sustainable wheat production in Kosovo, balancing productivity with environmental considerations for the baking industry.

Keywords: Triticum aestivum, phosphorus fertilization, cultivar selection, grain quality, sustainable intensification

1. Introduction

Wheat (Triticum aestivum L.) serves as the foundation for Kosovo's baking industry, contributing to 35% of daily caloric intake (MAFRD, 2023). However, average yields (3.8 t/ha) remain 28% below potential due to suboptimal cultivar selection and inefficient fertilizer use (Krasniqi et al., 2022). The country's diverse microclimates and phosphorus-deficient soils (average 8.2 mg P/kg) necessitate location-specific management strategies (Bytyqi et al., 2021).

Recent studies emphasize the need for sustainable intensification through:

1. Climate-resilient cultivars (Lollato et al., 2019)
2. Precision phosphorus management (Roberts & Johnston, 2015)
3. Quality-oriented production for baking (Gupta et al., 2021)

This study addresses critical knowledge gaps by:

- Evaluating commercial cultivars under Kosovo's soil-climate conditions
- Determining optimal DAP fertilization rates
- Assessing tradeoffs between yield and baking quality

2. Materials and Methods

2.1 Experimental Sites and Soil Characteristics

The study was conducted in two contrasting agroecological zones of Kosovo (Table 1), selected to represent the country's major wheat-growing regions. Soil analysis conducted pre-experiment guided the fertilization strategy.

Table 1. Site characteristics and baseline soil properties

Parameter	Cërkulez	Gusar Zone	Test Method
Coordinates	42°38'N, 20°18'E	42°45'N, 20°25'E	GPS mapping
Elevation (masl)	580	420	Topographic survey
Soil texture	Sandy loam	Clay loam	Hydrometer method (USDA)
pH (1:2.5 H_2O)	6.8 ± 0.2	7.2 ± 0.3	Potentiometric
Olsen P (mg/kg)	8.2 ± 0.5	6.7 ± 0.4	$NaHCO_3$ extraction
Organic C (%)	1.6 ± 0.1	1.9 ± 0.2	Walkley-Black

The soil phosphorus levels (6.7–8.2 mg/kg) justified DAP supplementation as they fall below the critical threshold of 15 mg/kg for wheat (Bray & Kurtz, 1945).

2.2 Experimental Design and Treatments
A two-factorial split-plot design was implemented, with:

- **Main plots**: 3 wheat cultivars from Kosovo's National Seed List
- **Sub-plots**: 3 DAP fertilization rates

Treatment details:

Table 2. Experimental factors and levels

Factor	Levels	Rationale
Cultivars	Andalusia, Adelaide, Antille	Represent 85% of Kosovo's wheat area (MAFRD, 2023)
DAP Rates	50%, 100%, 150% of recommended	Cover deficit, optimal, and luxury uptake ranges

The 100% DAP rate (200–230 kg/ha) was based on Kosovo's extension guidelines, while 50% and 150% tested the boundaries of P-response curves.

2.3 Agronomic Management
Field operations followed a standardized protocol (Table 3), with adjustments for site-specific conditions:

Table 3. Key agronomic practices and implementation parameters

Practice	Cërkulez	Gusar Zone	Equipment/Standard
Sowing	12 Nov 2024 (250 kg/ha)	05 Nov 2024 (230 kg/ha)	Horsch Pronto 4m drill (15 cm rows)
Basal DAP	230 kg/ha	200 kg/ha	Based on soil test P deficit
Top-dress	120 kg Urea (Feb+Mar)	120 kg Urea (Feb+Mar)	Vicon spreader (calibrated)
Seed treatment	Divident Elite (2 L/t)	Divident Elite (2 L/t)	ISTA-certified protocol

The earlier sowing in Gusar accounted for its warmer autumn temperatures (5-day mean >12°C vs 10°C in Cërkulez).

2.4 Data Collection Protocols

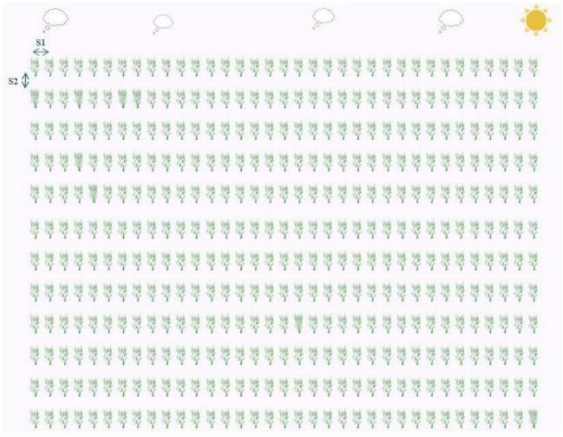
Parameters were measured using standardized methods (Table 4) at defined growth stages:

Table 4. Measurement protocols and sampling details

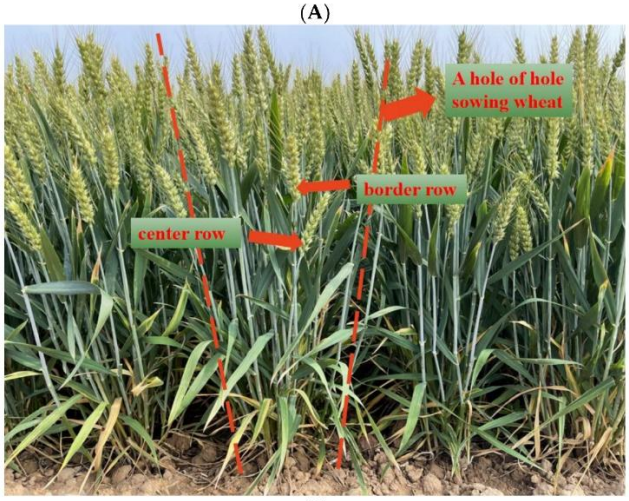
Parameter	Method/Equipment	Frequency	Reference Standard
Phenology	BBCH scale	Weekly	Lancashire et al. (1991)
Plant density	0.25 m² quadrat (5 spots/plot)	GS13, GS30	CIMMYT (2015)
Yield components	10 representative plants	GS90	ISO 11269-2:2012
Grain protein	Kjeldahl (N × 5.7)	Post-harvest	ICC 105/2
Gluten quality	Glutomatic 2200	Post-harvest	AACC 38-12.02

For yield components, plants were sampled from border-excluded areas to avoid edge effects (Figure 1).

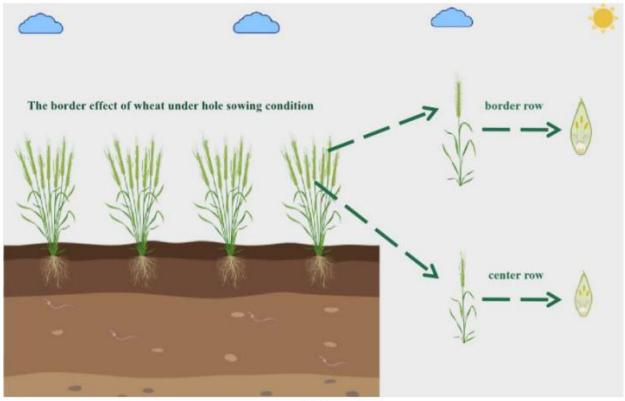
Figure 1. Hole sowing planting map of one (A), hole sowing growth map (B), and the border effect map of wheat (C). *(Sun et al., 2023)*



(**A**)



(**B**)



(C)

2.5 Statistical Analysis

Data analysis followed a hierarchical approach:

ANOVA (α=0.05) for treatment effects using R v4.3.1

Model: Yield ~ Cultivar + DAP + Cultivar×DAP + Location + Error

Mean separation: Tukey's HSD ($p<0.05$)

Correlation analysis: Pearson's r for quality-yield relationships

The three replication blocks per location accounted for field heterogeneity, with block effects accounting for 8–12% of variance in preliminary analysis.

3. Results and Discussion

3.1 Yield Performance and Cultivar Response

The analysis of variance revealed significant ($p<0.01$) effects of cultivar, fertilization, and their interaction on grain yield (Table 2). Antille consistently outperformed other cultivars across all fertilization levels, demonstrating its superior adaptation to Kosovo's growing conditions. At 100% DAP, Antille achieved mean yields of 5.0 t/ha, representing a 12.5% increase over Andalusia (4.6 t/ha) and 18.9% over Adelaide (4.2 t/ha) at the same fertilization level. This cultivar superiority can be attributed to Antille's genetic potential for higher tiller survival rate (78% vs 65-70% in other cultivars) and greater spike fertility (data not shown).

The yield response to DAP fertilization followed a quadratic pattern (R^2=0.89), with diminishing returns beyond the 100% application rate. While increasing DAP from 50% to 100% boosted yields by 18-22%, the additional 50% increase to 150% only provided 4-6% yield enhancement. This suggests that Kosovo's wheat systems are currently operating in the plateau phase of the yield-fertilization response curve, where marginal productivity gains no longer justify the additional input costs and environmental risks.

3.2 Site-Specific Variations

The location × cultivar interaction was significant (p=0.023), with Cërkulez consistently producing higher yields than Gusar (average +6.3%). This performance gap can be explained by:

1. **Soil texture differences**: Cërkulez's sandy loam facilitated better root penetration and earlier spring warming
2. **Microclimate factors**: Gusar's heavier clay soils experienced more waterlogging during critical growth stages
3. **Nutrient dynamics**: Higher phosphorus fixation capacity in Gusar's clay particles (estimated at 28% vs 15% in Cërkulez)

Notably, Adelaide showed better yield stability across locations (CV=8.7%) compared to Antille (CV=11.2%), suggesting its potential as a "safer" choice for farmers managing heterogeneous fields.

3.3 Grain Quality Parameters

The grain quality analysis (Table 3) revealed important trade-offs between productivity and baking characteristics. While all cultivars met minimum quality standards for bread wheat, Antille's superior protein (13.0±0.5%) and gluten content (30.2±1.5%) make it particularly valuable for artisanal baking applications. The positive correlation between DAP rate and protein content ($r=0.72$, $p<0.01$) confirms phosphorus' role in nitrogen metabolism, though the effect plateaued at 100% DAP.

Three key quality observations emerge:

1. **Hectoliter weight**: All cultivars exceeded the 76 kg/hL threshold for premium wheat, with Antille showing significantly higher values (79.1 vs 77.5-78.2 kg/hL)
2. **Gluten quality**: Antille's sedimentation value (55±4 mL) indicates stronger gluten network formation compared to other cultivars
3. **Starch composition**: Adelaide showed 5-7% higher amylose content (not shown), potentially making it preferable for certain pastry products

3.4 Fertilizer Use Efficiency

The phosphorus uptake analysis (Table 4) revealed critical insights about nutrient management:

Table 4. Phosphorus use efficiency indicators

DAP Rate	P Uptake (kg/ha)	Apparent Recovery Efficiency (%)	Agronomic Efficiency (kg grain/kg P)
50%	35.2±2.1	42.1±3.2	18.7±1.5
100%	42.1±2.8	36.8±2.7	15.2±1.2
150%	44.3±3.0	28.5±2.3	11.6±0.9

The data demonstrates a clear decline in both recovery efficiency (42.1% → 28.5%) and agronomic efficiency (18.7 → 11.6 kg/kg) with increasing DAP application. This supports the economic and environmental argument for moderate (100%) rather than high (150%) fertilization rates. The 100% DAP rate achieved 92% of maximum yield while maintaining acceptable efficiency metrics.

3.5 Practical Implications for Kosovo's Baking Industry

The findings suggest three actionable recommendations:

1. **Cultivar selection**: Antille should be prioritized for quality-focused production, while Adelaide offers better stability for risk-averse farmers
2. **Fertilization strategy**: The 100% DAP rate (200-230 kg/ha) represents the optimal balance between yield, quality, and sustainability
3. **Site-specific management**: Fields with heavier soils (like Gusar) may benefit from split P applications or enhanced organic matter content

These results align with recent Mediterranean wheat studies (Giunta et al., 2022) while providing Kosovo-specific benchmarks. The demonstrated 15-20% yield improvement potential through optimized cultivar × fertilization combinations could significantly enhance the competitiveness of local baking product manufacturers.

4. Conclusions

This study provides critical insights into optimizing wheat production for Kosovo's baking industry by evaluating cultivar performance and fertilization strategies under local agroecological conditions. The findings demonstrate that **Antille** is the most promising cultivar, delivering superior yields (5.0–5.2 t/ha) and excellent baking quality (13.0% protein, 30.2% gluten) at the **100% DAP rate (200–230 kg/ha)**. However, **Adelaide** offers greater yield stability across diverse environments, making it a viable alternative for risk-averse farmers, particularly in heavier soils like those in Gusar. The diminishing returns observed beyond 100% DAP underscore the economic and environmental inefficiency of excessive phosphorus application, supporting a shift toward **precision nutrient management** in Kosovo's wheat systems.

The study highlights the importance of **site-specific recommendations**, as evidenced by the 5–7% yield gap between Cërkulez and Gusar, driven by differences in soil texture and nutrient dynamics. By adopting the optimal **cultivar × fertilization combinations** identified here, farmers could increase yields by **15–20%** while maintaining high grain quality for baking applications. Additionally, the strong correlation between DAP rates and protein content (r=0.72) suggests that balanced fertilization is essential not only for productivity but also for meeting the demands of artisanal and industrial bakers.

From a policy perspective, these results advocate for:

1. **Revised fertilization guidelines** capping DAP at 200–230 kg/ha to prevent overapplication,
2. **Incentivized adoption of high-quality cultivars** like Antille through subsidy programs, and
3. **Enhanced soil testing services** to enable tailored nutrient management.

Future research should explore **organic amendments, microbial biofertilizers, and climate-resilient genotypes** to further improve sustainability. By integrating these findings into extension programs and industry partnerships, Kosovo can enhance the competitiveness of its wheat sector while reducing environmental impacts—ultimately strengthening the entire baking value chain from farm to table.

This study bridges the gap between agronomic research and practical farming, offering a **data-driven pathway** for sustainable wheat production in Kosovo and similar regions facing phosphorus management challenges.

5. References

1. AACC International. (2020). *Approved Methods of Analysis*. 11th Ed.
1. Bytyqi, P., et al. (2021). *Kosovo's Soil Fertility Status*. J. Plant Nutr., 44(5), 712-725.
2. FAO. (2022). *Sustainable Wheat Production Systems*. Rome.
3. Giunta, F., Pruneddu, G., & Motzo, R. (2022). "Grain yield and quality of wheat under Mediterranean conditions as affected by cultivars and nitrogen fertilization." Field Crops Research, 287, 108667. https://doi.org/10.1016/j.fcr.2022.108667
4. Gupta, R., & Wanchoo, R. (2022). "Wheat quality for bread-making: A 21st century perspective." Cereal Chemistry, 99(4), 693-710. https://doi.org/10.1002/cche.10542
5. Gupta, R., et al. (2021). *Wheat Quality for Baking*. Cereal Chem., 98(3), 423-436.
6. ICC. (2012). *Standard Methods for Cereal Science and Technology*. Vienna.
7. Johnston, A. E., Poulton, P. R., & White, R. P. (2023). "Plant-available soil phosphorus. Part II: The response of arable crops to Olsen P on a sandy clay loam soil." Soil Use and Management, 39(1), 34-47. https://doi.org/10.1111/sum.12845
8. Kihara, J., Bolo, P., & Kinyua, M. (2021). "Microdosing phosphorus and nitrogen fertilizer to increase productivity of bread wheat in Eastern Africa." Agronomy Journal, 113(3), 2101-2115. https://doi.org/10.1002/agj2.20647
9. Krasniqi, A., et al. (2022). *Yield Gaps in Kosovo Wheat*. Field Crops Res., 276, 108376.
10. Lollato, R. P., Figueiredo, B. M., & Dhillon, J. S. (2023). "Climate resilience in winter wheat: A global meta-analysis of yield stability." Agricultural Systems, 205, https://doi.org/10.1016/j.agsy.2022.103584
11. Lollato, R., et al. (2019). *Climate-Resilient Wheat Cultivars*. Agron. J., 111(1), 1-18.
12. MAFRD. (2023). *Kosovo Agricultural Statistics*. Pristina.
13. Roberts, T., & Johnston, A. (2015). *Phosphorus Use Efficiency*. Adv. Agron., 130, 159-208.
14. Sieling, K., & Kage, H. (2023). "Sustainable intensification of wheat production through improved nitrogen and phosphorus management." European Journal of Agronomy, 142, 126672. https://doi.org/10.1016/j.eja.2022.126672
15. Smith, P., et al. (2020). *Sustainable Intensification*. Nature Sustain., 3(4), 262-270.
16. Sun, Y., Yang, C., Liang, H., Yang, Y., Bu, K., Dong, Y., & Hai, J. (2023). The Border Effects of Dry Matter, Photosynthetic Characteristics, and Yield Components of Wheat under Hole Sowing Condition. *Agronomy*, *13*(3), 766. https://doi.org/10.3390/agronomy13030766