RESEARCH REGARDING PRODUCTION POTENTIAL DEPENDING ON FLAG LEAF AREA AND SPIKE LENGTH, IN THREE SPECIES OF GRASSY CEREALS CULTIVATED ON THE CHERNOZEM OF CARACAL

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Abstract

The flag leaf is very important in the life of cereals, as it contributes to the total amount of photoassimilates, to the grain filling process, and to the dry matter content of the grain at maturity, thus playing an essential role in total productivity.

This study presents some experimental results from the SCDA Caracal (Dolj County, Romania) regarding production potential depending on flag leaf area and spike length, in three species of grassy cereals (wheat, triticale and barley), cultivated on the chernozem soil (2022-2024). A three-factorial experience was set up in 3 x 3 x 4 randomized blocks. The influence of the studied factors (species, growing season, flag leaf area) and the interaction species x growing season x flag leaf area on potential production was interpreted. Potential production was greatly influenced by the flag leaf and spike area, both the flag leaf cut in half, the flag leaf cut completely and the spike cut ½ resulted in very significant production reductions. However, the lack of the flag leaf or its reduction did not lead to a major reduction in production, as has been recorded in some literature studies.

***Key words**: production, wheat, triticale, barley, flag leaf*

INTRODUCTION

All over the world, food safety and security have become major concerns (Ciğerci et al., 2023; Rosculete et al., 2018).

Grassy cereals (wheat, triticale and barley) are important for both human nutrition and environmental health, providing essential nutrients, supporting digestive and cardiovascular health, and improving soil quality by preventing erosion and increasing organic matter. They are a staple food source for much of the world's population and are crucial for livestock feed. Thus, cereals are packed with vitamins, minerals, antioxidants, and all essential amino acids (Garutti et al., 2022). They may reduce the risk of developing certain diseases (Nirmala Prasadi and Joye, 2020; Tieri et al., 2020; Zhu et al., 2017).

Regarding the environmental and agricultural importance, the extensive root systems of the wheat, triticale and barley improve soil structure, prevent erosion, and increase organic matter by leaving behind residue. As cover crops, they quickly establish a ground cover that suppresses weeds and protects the soil from erosion.

The flag leaf is the final leaf that emerges on a cereal plant, and its photosynthetic output is a primary driver of final grain yield (Ba et al., 2020; Du et al., 2022; Kumar et al., 2024). Spike length is a major yield component that directly influences the number of spikelets and, consequently, the number of potential grains per spike. Both the flag leaf area and spike length are crucial factors influencing the potential production of cereals, but they contribute to yield through different physiological mechanisms. A large, healthy flag leaf ensures a high supply of carbohydrates for grain filling, while a long spike provides the physical capacity for a greater number of kernels.

Flag leaf traits are considered to have an important role in grain filling of grassy cereals under drought conditions. Thus, physiological, morphological and biochemical traits of flag leaves are involved in determining grain yield and biomass (Liu et al., 2015; Racz et al., 2022).

Heat stress results in reduced grain number per spike and ability of pollen germination in the anthesis stage and yield losses (Duan et al., 2025; Tao et al., 2015). Different crops respond differently to these climate-related challenges, with some being more resilient than others are (Paraschivu et al., 2017, 2021, 2022; Dima et al, 2023). However, for many crops, the impacts of climate change may outweigh their ability to adapt, resulting in decreased productivity and economic losses for farmers (Velea et al, 2021). As such, it is crucial for agricultural research and policy to prioritize strategies for mitigating and adapting to the effects of climate change on crop performance to ensure food security for a growing global population.

MATERIALS AND METHODS

A three-factorial experience was set up in 3 x 3 x 4 randomized blocks, as follows:

- factor a – species: a1-wheat; a2-triticale; a3-barley;
- factor b – vegetation period: b1 – early; b2 –medium; b3 - late;
- factor c – flag leaf area: c1- entire flag leaf; c2- flag leaf cut to ½ at earing; c3- flag leaf cut completely at earing; c4 - ear cut to ½ at earing with entire flag leaf;

The biological material consisted of:

- Wheat cultivars with differentiated earing: Amurg (early); Carom (medium/+3-4 days); Bogdana (late/+7-8 days)
- Triticale cultivars with differentiated earing; 11588t2-23 (early); Utrifun (medium/+4-5 days); Inspector (late/+14-15 days)
- Barley cultivar with differentiated earing; F 8-4-12 (early); Ametist (medium/+3-4 days); Onix (late/+7-8 days).

The influence of the studied factors (species, vegetation period, flag leaf area) and the interaction species x vegetation period x flag leaf area on the potential production was interpreted.

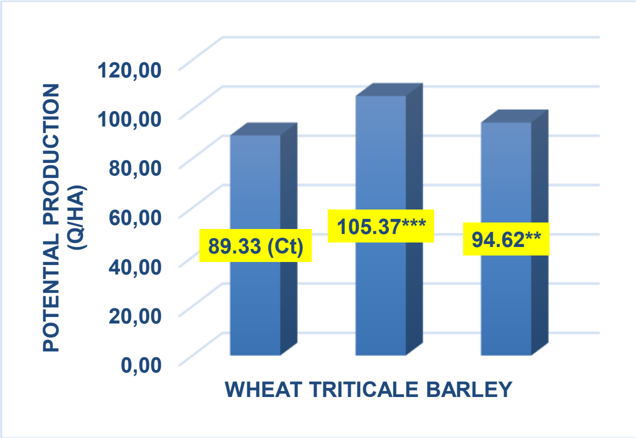
For each species and vegetation period, 30 plants were randomly selected for each C factor grading and marked as follows: for c1 – blue raffia thread; for c2 – yellow raffia thread; for c3 – red raffia thread; for c4 – white raffia thread. Leaf cuttings (1/2 and total) and spikes (1/2) were performed immediately after earing. Most of the field determinations and all laboratory determinations were performed on these plants.

In the 2022-2023 agricultural year, precipitation totalized 456.8 mm throughout the entire vegetation period, the multiannual average being 389.5 mm. Regarding the 2023-2024, sowing was carried out late, after a successful application of irrigation to help prepare the seedbed. Temperatures were extremely high for the months of September and October. These were recorded against the backdrop of an acute lack of precipitation.

RESULTS AND DISCUSSIONS

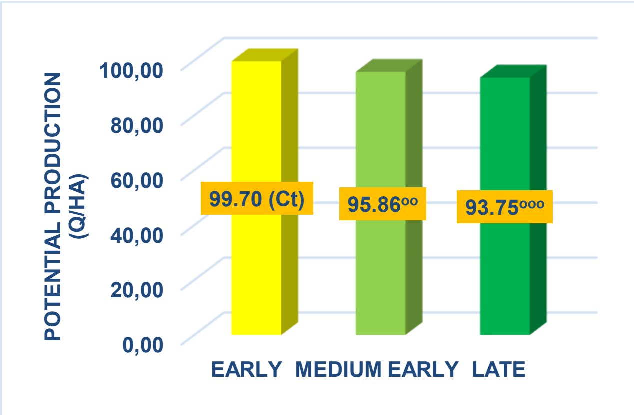
Drought creates a water deficit with greatest impact on cereals production (Paunescu et al., 2021, 2023, Rosculete et al., 2021). Biotechnological tools have highly contributed to the grains production and supply of improved the quality seed (Bonciu et al., 2021; De Souza and Bonciu, 2022). To keep up with the demand, modern strategies need to be developed to increase wheat yield under this changing environment (Bonciu et al., 2021a,b).

The potential production was calculated based on the number of ears/m^2 in each plot and the weight of grains per ear depending on their origin: plants with intact flag leaf, plants with flag leaf cut to ½, plants with flag leaf cut completely and plants with ear cut to ½ but with whole flag leaf. On average over the 2 years, the species significantly influenced the potential production. Both barley and triticale showed distinct and very significant production increases compared to wheat (Figure 1). The influence of earliness was equally significant. Medium-early and late varieties showed significant decreases in potential production compared to early varieties (Figure 2).



LD 5% = 2.56 q/ha; LD 1% = 4.23 q/ha; LD 0,1% = 7.92 q/ha

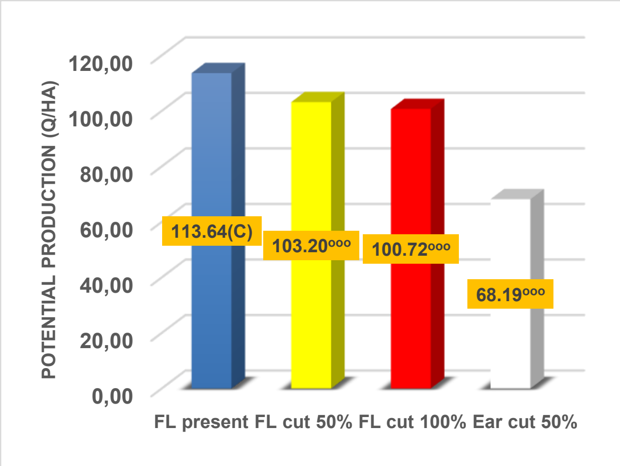
Figure 1. Influence of species (factor A) on potential production in wheat, triticale and barley, regardless of earliness and flag leaf and spike surface area – Caracal 2023+2024



LD 5% = 2.13 q/ha; LD 1% = 2.99 q/ha; LD 0,1% = 4.22 q/ha

Figure 2. The influence of earliness (factor B) on the potential production of wheat, triticale and barley, regardless of species and flag leaf and spike surface area – Caracal 2023+2024

Potential production was also greatly influenced by the surface area of the flag leaf and the spike, both the flag leaf (FL) cut in half, the flag leaf cut completely, and the spike cut by ½ resulted in very significant production decreases (Figure 3). In percentage terms, reducing the flag leaf by half its area reduced production by 9%. The total lack of the flag leaf led to an 11% decrease in production and halving the spike caused a 40% loss in production (Figure 4).



LD 5% = 2.14 q/ha; LD 1% = 2.86 q/ha; LD 0,1% = 3.72 q/ha

Figure 3. Influence of flag leaf (FL) and spike surface area (C factor) on potential production in wheat, triticale and barley, regardless of species and earliness – Caracal 2023+2024

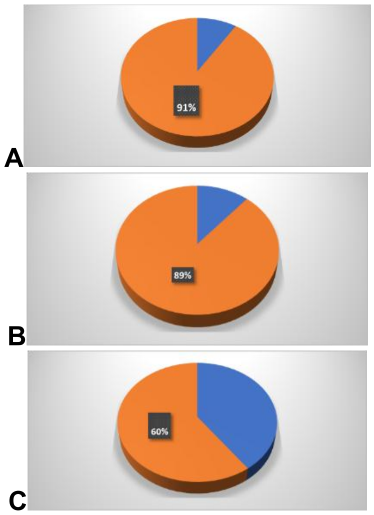


Figure 4. Graphical representation of production according to the area of the flag leaf and the spike in percentages: A – flag leaf cut in half at the ear; B – flag leaf cut completely at the ear; C – ear cut in half at the ear and the flag leaf whole (average 2023-2024)

The three-factor interaction species (factor A) x earliness (factor B) x flag leaf and spike area (factor C) greatly influenced the yield. In most combinations, the potential yield was greatly reduced, mainly very significantly (Table 1).

Early triticale varieties, regardless of the degree of reduction in leaf area, presented very significant potential production increases compared to the control - wheat species, early variety with an entire flag leaf.

Compared to both controls, the potential production of the tested species and at all levels of precocity when the spike was cut in half was very significantly reduced. In conclusion, any damage to the spike either by climatic conditions (hail, storm), or by mechanical conditions (spike breakage due to incorrect use of agricultural machinery), or by destructive actions (animal penetration into the fields), leads to a significant quantitative loss of production.

The relationship between flag leaf area and spike length is complex and interdependent. A long spike with a large number of potential grains is only beneficial if the plant's photosynthetic capacity, largely driven by the flag leaf, is sufficient to fill all those grains. If environmental stress or poor flag leaf health limits the supply of carbohydrates, a long spike may result in poorly filled, lighter grains, rather than a significant yield increase. High-yielding genotypes are often characterized by a favourable balance between these two traits, ensuring that the plant has both the physical potential for many grains (long spike) and the metabolic capacity to properly fill them (large, healthy flag leaf).

Table 1. Influence of the interaction species (factor A) x earliness (factor B) x flag leaf (FL) and ear area (factor C) on wheat, triticale and barley production – Caracal 2023+2024

FACTOR A	FACTOR B	FACTOR C	Producţion (q/ha)	Dif. Ct 1	Signific.	Dif. Ct 2	Signific.
WHEAT	Early	FL present	108.95	0.00			
WHEAT	Early	FL present	108.95	0.00		0.00	
		FL cut 50%	100.93	-8.02	o	-8.02	o
		FL cut 100%	87.31	-21.64	ooo	-21.64	ooo
		Ear cut 50%	55.60	-53.35	ooo	-53.35	ooo
	Medium early	FL present	93.72	-15.23	ooo	0.00	
		FL cut 50%	84.62	-24.33	ooo	-9.10	oo
		FL cut 100%	83.32	-25.63	ooo	-10.40	oo
		Ear cut 50%	62.84	-46.11	ooo	-30.88	ooo
	Late	FL present	116.05	7.10	*	0.00	
		FL cut 50%	104.38	-4.57		-11.67	ooo
		FL cut 100%	103.10	-5.85		-12.95	ooo
		Ear cut 50%	71.17	-37.78	ooo	-44.88	ooo
TRITICALE	Early	FL present	142.36	33.41	***	0.00	
		FL cut 50%	133.25	24.30	***	-9.11	oo
		FL cut 100%	124.28	15.33	***	-18.08	ooo
		Ear cut 50%	98.67	-10.28	oo	-43.69	ooo
	Medium early	FL present	136.06	27.11	***	0.00	
		FL cut 50%	103.64	-5.31		-32.42	ooo
		FL cut 100%	108.75	-0.20		-27.31	ooo
		Ear cut 50%	78.59	-30.36	ooo	-57.47	ooo
	Late	FL present	99.98	-8.97	oo	0.00	
		FL cut 50%	88.62	-20.33	ooo	-11.36	ooo
		FL cut 100%	88.93	-20.02	ooo	-11.05	oo
		Ear cut 50%	61.27	-47.68	ooo	-38.71	ooo
Barley	Early	FL present	98.12	-10.83	oo	0.00	
		FL cut 50%	95.91	-13.04	ooo	-2.21	
		FL cut 100%	98.03	-10.92	oo	-0.09	
		Ear cut 50%	53.02	-55.93	ooo	-45.10	ooo
	Medium early	FL present	112.90	3.95		0.00	
		FL cut 50%	108.05	-0.90		-4.85	
		FL cut 100%	107.13	-1.82		-5.77	
		Ear cut 50%	70.74	-38.21	ooo	-42.16	ooo
	Late	FL present	114.66	5.71		0.00	
		FL cut 50%	109.39	0.44		-5.27	
		FL cut 100%	105.64	-3.31		-9.02	oo
		Ear cut 50%	61.85	-47.10	ooo	-52.81	ooo
	LD 5%		6.42 q/ha				
	LD 1%		8.56 q/ha				
	LD 0.1%		11.15 q/ha				

CONCLUSIONS

The potential production was greatly influenced by the flag leaf and spike area, both the flag leaf cut in half, the flag leaf cut completely and the spike cut ½ resulted in very significant production reductions. However, as a percentage, the lack of the flag leaf or its reduction does not lead to a major reduction in production, as has been recorded in the specialized literature.

Reducing the flag leaf by half of its area reduced production by 9%. The total lack of the flag leaf led to a decrease in production by 11% and halving the spike caused a loss of 40% of production.

The interaction species x earliness x flag leaf and spike area strongly influenced the potential production.

REFERENCES

Ba, Q., Zhang, L., Chen, S. et al. (2020) Effects of foliar application of magnesium sulfate on photosynthetic characteristics, dry matter accumulation and its translocation, and carbohydrate metabolism in grain during wheat grain filling. *Cereal Res Commun*, 48:157–163.

Bonciu, E., Liman, R., Cigerci, I.H. (2021). Genetic Bioengineering in agriculture-A model system for study of the mechanism of programmed cell death. *Scientific Papers: Management, Economic Engineering in Agriculture and Rural Development*, 21(4): 65-70.

Bonciu, E., Păunescu, R.A., Roșculete, E., Păunescu, G. (2021a). Waste management in agriculture. *Scientific Papers: Management, Economic Engineering in Agriculture and Rural Development*, 21(3): 219-227.

Bonciu, E., Păunescu, R.A., Roșculete, E., Florea, D. (2021b). The variability of some characters and their correlations with the yield of an extensive assortment of autumn wheat varieties, tested on the chernozem from ARDS Caracal. *Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series*, 51(1), 244-260.

Ciğerci, İ.H., Liman, R., Istifli, ES., Akyil, D., Ozkara, A., Bonciu, E., Cola, F. (2023). Cyto-Genotoxic and Behavioral Effects of Flubendiamide in *Allium cepa* Root Cells, *Drosophila melanogaster* and Molecular Docking Studies. *International Journal of Molecular Sciences*, 24(2):1565.

De Souza, C.P., Bonciu, E. (2022). Use of molecular markers in plant bioengineering. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, Vol. 22(1): 159-166.

Dima, M., Diaconu, A., Paraschivu, M., Cotuna, O., Sărățeanu, V., Bonciu, E., Sălceanu, C., Olaru, A.O. (2023). The impact of cultivation system on nutritional quality of Jerusalem artichoke tubers cultivated in semiarid marginal areas. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 51(2), 13210.

Du, B., Wu, J., Islam, M.S. et al. (2022) Genome-wide meta-analysis of QTL for morphological related traits of flag leaf in bread wheat. *PLoS ONE*, 17:1–19.

Duan, S., Meng, X., Zhang, H., Wang, X. et al. (2025). The Effect of Heat Stress on Wheat Flag Leaves Revealed by Metabolome and Transcriptome Analyses During the Reproductive Stage. *International Journal of Molecular Sciences*, 26(4):1468.

Garutti, M., Nevola, G., Mazzeo, R., Cucciniello, L. et al. (2022). The Impact of Cereal Grain Composition on the Health and Disease Outcomes. *Front Nutr*., 9, 888974.

Kumar, P., Gill, H.S., Singh, M. et al. (2024). Characterization of flag leaf morphology identifies a major genomic region controlling flag leaf angle in the US winter wheat (*Triticum aestivum* L.). *Theor. Appl. Genet*., 137, 205.

Liu, X.J., Yin, B., Hu, Z., Bao, X., Wang, Y., Zhen, W. (2021). Physiological response of flag leaf and yield formation of winter wheat under different spring restrictive irrigation regimes in the Haihe Plain, China. *Journal of Integrative Agriculture*, 20(9): 2343-2359.

Nirmala Prasadi, V.P., Joye, I.J. (2020). Dietary fibre from whole grains and their benefits on metabolic health. *Nutrients*, 12:1–20.

Paraschivu, M., Cotuna, O., Olaru, L., Paraschivu, M. (2017). Impact of climate change on wheat-pathogen interactions and concerning about food security. *Research Journal of Agricultural Science*, Vol.49 (3), 87-95.

Paraschivu, M., Matei, G., Cotuna, O., Paraschivu, M., Drăghici, R. (2022). Management of pests and pathogens in rye crop in dry marginal environment in Southern Romania. *Scientific Papers. Series A. Agronomy*, Vol. LXV, No. 1, 466-474.

Paraschivu, M., Matei, G., Cotuna, O., Paraschivu, M., Drăghici, R. (2021). Reaction of rye cultivars to leaf rust (*P. recondita f. sp. secalis*) in the context of climate change in dry area in southern Romania. *Scientific Papers. Series A. Agronomy*, Vol. LXIV, No. 1, 500-507.

Paunescu, R.A., Bonciu, E., Rosculete, E., Paunescu, G., Rosculete, C.A. (2023). The Effect of Different Cropping Systems on Yield, Quality, Productivity Elements, and Morphological Characters in Wheat (*Triticum aestivum*). *Plants*, 12, 2802.

Paunescu, R.A., Bonciu, E. Rosculete, E., Paunescu, G., Rosculete, C.A., Babeanu, C. (2021). The Variability for the Biochemical Indicators at the Winter Wheat Assortment and Identifying the Sources with a High Antioxidant Activity. *Plants*, 10(11), 2443.

Racz, I., Hirişcău, D., Berindean, I., Kadar, R., Muntean, E., Tritean, N., Russu, F., Ona, A., Muntean, L. (2022). The Influence of Flag Leaf Removal and Its Characteristics on Main Yield Components and Yield Quality Indices on Wheat. *Agronomy*, 12, 2545.

Rosculete, E., Bonciu, E., Rosculete, C.A., Teleanu, E. (2018). Detection and Quantification of Genetically Modified Soybean in Some Food and Feed Products. A Case Study on Products Available on Romanian Market. *Sustainability*, 10(5), 1325.

Roșculete, E., Păunescu, R.A., Bonciu, E., Roșculete, C.A., Voicea, I. (2021). Where are the foreign wheat cultivars in competition with the romanian cultivars? - Experiments on the chernozem from Caracal in the period 2019-2021. *Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series*, 51(1), 144-158.

Smýkal, P., Aubert, G., Burstin, J., et al. (2012). Pea (*Pisum sativum* L.) in the genomic era. *Agronomy,* 2(4):74–115.

Tao, F., Zhang, Z., Zhang, S., Rötter, R.P. (2015). Heat stress impacts on wheat growth and yield were reduced in the Huang-Huai-Hai Plain of China in the past three decades. *Eur. J. Agron*., 71, 44–52.

Tieri, M., Ghelfi, F., Vitale, M., Vetrani, C., Marventano, S., et al. (2020). Whole grain consumption and human health: an umbrella review of observational studies. *Int J Food Sci Nutr.,* 71:668–77.

Velea, L., Bojariu, R., Burada, C., Udristioiu, M.T., Paraschivu, M., Roxana Diana Burce, R.D. (2021). Characteristics of extreme temperatures relevant for agriculture in the near future (2021-2040) in Romania. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*. Vol. X, 70-75.

Yurkevich, O.Y., Samatadze, T.E., Levinskikh, M.A., Zoshchuk, S.A., Signalova, O.B., Surzhikov, S.A., Sychev, V.N., Amosova, A.V., Muravenko, O.V. (2018). Molecular Cytogenetics of Pisum sativum L. Grown under Spaceflight-Related Stress. *Biomed Res Int.*, 4549294.

Zhu, Y., Sang, S. (2017). Phytochemicals in whole grain wheat and their health-promoting effects. *Mol Nutr Food Res.*, 61:10347–10352.