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OPPORTUNITIES AND CHALLENGES OF SPEED BREEDING IN SPRING WHEAT

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Abstract. *Breeding of new and high performing spring wheat cultivars with preferred traits take more than 10 years but speed breeding method has the potential to reduce the time required for cultivar development, release and commercialization. The advantages of speed breeding consisted in release of pure line cultivars in ~5 years versus 10 to 14 years when using traditional methods. Notable breeding goals of spring wheat include higher yield potential and nutritional quality, and enhanced tolerance to biotic and abiotic stresses. The method saves breeding time and resources through rapid generation advancement, in our case, at least two per year. Speed breeding techniques depends on the manipulation of photoperiod, light intensity, temperature, soil moisture, soil nutrition and high-density planting. These methods are used for induce early flowering and seed set, reducing the time taken to generate each breeding generation, for example from seeding to heading 38 days were necessary for obtain the second generation in 22 hours light/2 hours darkness conditions and we obtain rapid growth, development, flowering and seed set. A number of six hybrid combinations in which were crossed indigenous spring wheat genotypes with genotypes from CIMMYT, for transmission valuable traits and characteristics such as 1000-kernel weight and earliness possessed by them were carried out.*

Keywords*: spring wheat, speed breeding, controlled conditions, generations/year*

INTRODUCTION

Of the global area sown with wheat, approximately 30% is occupied by spring varieties. Typical spring wheat completes the vernalization stage in a few days at temperatures between 5 and 20°C, but many spring wheat varieties do not require vernalization to produce seeds. The introduction of spring wheat varieties allowed the expansion of wheat cultivation into more northerly regions of the globe where winter wheat cannot withstand the extremely low temperatures of winter, succumbing to frost damage or can't survive when a snow cover remains on the ground for an extended period, which can exceed six months. The solution was the creation of spring wheat varieties with a growing season of less than 100 days. Canada in a good example which become a wheat-exporting country by cultivation of very early-maturing spring wheat varieties. According to Eurostat statistics, the United States ranked first place in the 2014–2015 season with over 25 million tonnes exported, followed by Canada in second place with 21 million tonnes, and Russia in third place with 19.5 million tonnes. That three countries mentioned predominantly grow spring wheat, which is more valuable in terms of quality indicators.

The breeding of new wheat varieties in the field is a lengthy process that can take more than 12 years. In greenhouses, producing 2–3 generations per year is normal, given that breeding protocols continue to improve in these controlled environments. The term "speed breeding" (SB) was invented in 2003 by University of Queensland, where techniques were developed that involve optimizing the light spectrum, light intensity, photoperiod, and temperature to accelerate photosynthesis and flowering time. Speed wheat breeding has enabled the production of 4–6 generations per year when was conducted under controlled

environmental conditions that promote rapid growth and early flowering and this process can be further accelerated by combining speed breeding (SB) with genomic selection (Speed GS), allowing new varieties to be registered in 5–7 years. The possibility of cultivating and breeding wheat in controlled environments was also investigated by NASA, at the University of Utah, in the early of 1980's and their efforts resulted in the development of a dwarf wheat line resistant to leaf-tip burn (USU-Apogee), which can flower in 25 days when grown at 23°C under continuous light and CO_2 concentration of 1000–1200 ppm. Although there is no consensus yet regarding intensity and spectrum of light, wheat grows best when is cultivated at temperatures of 21–23°C during the day and 18–20°C at night, with high CO_2 concentrations.

Challenges in spring wheat breeding

Wheat breeding objectives are aligned with climate change, which manifests through rising average temperatures, more frequent and severe heat waves, and extended periods of drought during critical phases of wheat phenology. The rise of average global temperatures is primarily due to the intensification of the greenhouse effect resulting from human activities, which release massive quantities of greenhouse gases, especially CO_2 into the atmosphere. The global average atmospheric concentration of carbon dioxide (CO_2) increased from approximately 270 ppm in the pre-industrial period to 360 ppm in 1994, and reached 422.5 ppm in 2024, with an upward trend. In 1998, it was projected that the CO_2 concentration would rise to 850 ppm by the year 2100, and this value depending on future CO_2 emissions into the atmosphere (KING et al, 1992). Increasing atmospheric CO_2 concentrations is beneficial for plants with C3-type photosynthesis, such as wheat. An increase in CO_2 concentration from 300–350 to 680 μl l^{-1} has been shown to enhance photosynthesis in crops with the C3 photosynthetic type by an average of 41–105% under short-term exposure or 13–42% under long-term exposure as well as to increase biomass and yield by 15–70% (CURE & ACOCK, 1986).

An increase in the rate of photosynthesis through CO_2 enrichment does not necessarily lead to an increase in production. Increasing production depends not only on the maximum rate of photosynthesis per unit area, but also on other components, such as leaf area and the duration for which the leaves remain green. Furthermore, in order to maintain a high rate of photosynthesis, photosynthetic products should be efficiently transferred from leaves to grains. Experiments with high CO_2 levels in controlled environments have produced significant increases in biomass and cereal yield (CURE & ACOCK, 1986). Fewer experiments have been conducted in the field, and the results have been more variable; the effect of CO_2 on biomass and yield depends on the variety tested, the temperature regime during the growing season (RAWSON, 1995), and the light intensity during periods critical for yield determination (FISCHER et al, 1981).

Increasing of drought years frequency, characterized by high temperatures and low precipitation, necessitates the adaptation of spring wheat varieties to these new environmental conditions. LIPIEC et al. (2013) define drought resistance as the ability of plants to withstand dehydration (resistance to desiccation) or overheating (resistance to heat stress). When the balance between water absorbed and water transpired is disrupted, the phenomenon of temporary wilting occurs. Although this does not lead to a total loss of plant vitality, it results in a reduction in yield due to the closure of the stomata during the midday hours. When soil drought occurs concurrently with atmospheric drought, an imbalance arises in the plants' water balance, leading to prolonged or permanent wilting. In Romania, CROITORU et al. (2009) studied climate change in the country during the 1901–2006 period and its impact on the growing season of wheat crops. Following this study, the authors found that the anthesis period

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in wheat occurred approximately 1–3 days earlier per decade, with the lowest values recorded in the western and north-western regions of the country, and the highest value in the south-eastern part. Furthermore, in the northern regions, in addition to a shortening of the growing season, a reduction in the grain-filling period by approximately 1 day per decade has also been observed. In the south eastern part, there were no changes in the grain-filling period during the time interval analysed.

Genetic approaches to extending the duration of green leaves are becoming increasingly important in spring wheat (*Triticum aestivum* L.) because rising temperatures accelerate leaf senescence but early heading was consistently associated with a longer GLDAH (Green Leaf Duration After Heading) across a wide range of environments (Ding et al, 2018). High temperatures during grain filling lead to more rapid leaf senescence and a shorter grain-filling duration (KUMAR et al, 2010). Photosynthesis in the wheat flag leaf contributes approximately 30 to 50% of assimilates required for grain filling. KALIQ et al. (2008) suggested that the duration for which the flag leaf remains green could be linked to yield potential. The delay in leaf senescence was correlated with a more developed and active root system (NAKAGAMI et al., 2004).

RESULTS AND DISCUSSIONS

In our country, the importance of spring wheat increases when difficulties arise in establishing winter wheat crops, as well as in regions where low temperatures set in early in the autumn, conditions under which a winter crop would be unable to survive the winter without significant losses. Wheat productivity is determined by two categories of factors: intrinsic factors, which relate to the biological material, and influencing factors. Intrinsic factors are represented by characteristic productivity elements such as: number of spikes per square meter, number of grains per spike, and thousand-kernel weight (TKW), as well as by a range of physiological and biochemical processes, including growth rate, earliness, resistance to lodging, and intensity of photosynthesis (SĂULESCU, 1986; SĂULESCU & JINGA, 1990). Production potential is constantly threatened by the influence of extreme natural conditions, which are highly unpredictable; furthermore, even when cultivation techniques are applied optimally, they cannot entirely counteract the negative impact of adverse environmental factors. Wheat varieties capable of tolerating such unfavourable conditions while simultaneously responding positively to optimal growing conditions provided through technological inputs are preferred, as they deliver high and stable yields that come as close as possible to their productive potential.

Research objectives:

Creating variability in spring wheat through controlled hybridizations between the most valuable germplasm sources available in the collection of ARDS Turda;

Establishing the basis for genetic progress in spring wheat, grounded in results obtained during the F2–F6 selection generations;

Accelerating the process of developing new spring wheat varieties by producing two generations per year and reducing the number of years required for their development, compared to the current practice, which necessitates 12–14 years;

Identification of productive genotypes that possess superior quality traits and are resistant to the low temperatures that occur sooner or later in the spring;

The transfer of valuable traits and characteristics, specifically earliness and higher thousand-kernel weight (TKW) values from CIMMYT derived germplasm to varieties and lines

developed at Agricultural Research and Development Station Turda (ARDS Turda) that are deficient in these aspects.

In 2026, between March 1 and October 10 we obtained two generations of spring wheat in a greenhouse, under the following conditions:

- Collection consisting of 40 genotypes, 27 local and 13 foreign was sown on March 1st. Emergence occurred between 4 and 6 of March;
- First hybridizations were carried out between genotypes originating from CIMMYT, which proved to be earlier-maturing, acting as the maternal parent, and the Ciprian variety, a facultative wheat variety, acting as the paternal parent, on May 2. The hybridization program continued until May 12, during which time we created 16 hybrid combinations. In the field, the same genotypes headed between May 28 and June 4;
- Three weeks after the flowering phase, we stopped watering in the greenhouse (May 31) to accelerate physiological maturity which took place around June 20th. In the field, physiological maturity for the same genotypes occurred around July 20;
- The seeds resulting from the hybrid combinations were sown in the greenhouse to obtain the second generation specifically, the F1 populations for the 16 combinations, on July 20. On August 27, the first F1 hybrids (the second generation in the greenhouse) reached the heading stage at 38 days after sowing;
- On October 10, the spikes from the 16 hybrid combinations were harvested, 82 days after sowing.

CONCLUSIONS

In recent years, in the context of climate change, both globally and within our own country, spring wheat has gained increasing importance, ARDS Turda is the only provider in Romania capable of supplying seeds for this crop.

In 2026, we obtained two generations per year in spring wheat and identified earlier-maturing genotypes, which passed this trait on to the F1 hybrids.

Fewer days, specifically 82, were required to obtain the second generation in the greenhouse, compared to the first generation (112 days); this was due to an increase in atmospheric temperature and the photoperiod.

For the future, in order to further accelerate the process of developing new spring wheat varieties, we will combine speed breeding with the single-seed selection method to more rapidly achieve a high degree of uniformity.

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BIBLIOGRAPHY

CROITORU, A.E., HOLOBACA, I.H., LAZAR, C. , MOLDOVAN, F., IMBROANE, A., 2012. Air temperature trend and the impact on winter wheat phenology in Romania. Climatic Change 111, 393–410, https://doi.org/10.1007/s10584-011-0133-6.

CURE, J.D. AND ACOCK, B., 1986. Crop Responses to Carbon Dioxide Doubling: A Literature Survey. Agricultural and Forest Meteorology, 38, 127-145. http://dx.doi.org/10.1016/0168-1923(86)90054-7

DING, H., LIU, D., LIU, X. et al., 2018. Photosynthetic and stomatal traits of spike and flag leaf of winter wheat (*Triticum aestivum* L.) under water deficit. Photosynthetica, 56, 687-697.

FISHER, R.A., DIDINGER, F.R., SYME J.R., AND WALL, P.C., 1981. Leaf photosinthesis, crop growth and yield of short spring wheat genotypes under irrigation. Crop Science 21: 367-373.

LIPIEC, J, DOUSSAN, C., NOSALEWICZ, A, KONDRACKA, K., 2013. Effect of drought and heat stresses on plant growth and yield: a review. International Agrophysics 27, 463-477, doi: 10.2478/intag-2013-0017

KHALIQ, I., IRSHAD, A., AHSAN, M., 2008. Awns and flag leaf contribution towards grain yield in spring wheat (*Triticum aestivum* L.). Cereal. Res. Commun., 36 (1), 65-76.

KING, A.W., WILLIAM, R., WILFRED, M., 1992. Projecting future concentration of atmospheric CO2 with global carbon cycle models: The importance of simulating historical changes. Environmental Managenent, Vol. 16, pp 91-108.

KUMAR, U., A.K. JOSHI, M. KUMARI, R. PALIWAL, S. KUMAR, AND M.S. RODER, 2010. Identification of QTLs for stay green trait in wheat (Triticum aestivum L.) in the 'Chirya 3' × 'Sonalika' population. Euphytica 174:437–445.

LEVY J., PETERSON, M.L., 1972. Responses of spring wheats to vernalization and photoperiod, Crop Science, vol. 12, p. 487–490.

NAKAGAMI, T., OOKAWA, HIRASAWA, T., 2004. Reduction in Soil Moisture from One Month before Flowering through Ripening on Dry Matter Production and Ecophysiological Characteristics of Wheat Plants. Plant Prod. Sci. 7 (2) : 143- 154

NĂSESCU, V., CRĂCIUN, I., CRĂCIUN, M., NIȚĂ, C., 1988. Rezultate privind efectele secetei survenite în diferite faze de creştere asupra formării producţiei la grâu. Probleme de agrofitotehnie teoretică şi aplicată, X, 4, 345-362.

SĂULESCU, N.N., 1986. Relaţia între data înspicatului şi producţie în experienţele cu soiuri de grâu efectuate în perioada 1975-1985. Probleme de genetică teoretică şi aplicată, XVIII,2,67-82.

SĂULESCU, N.N., JINGA, E., 1990. Estimarea unor caracteristici ale ideotipului de grâu pentru Câmpia Română folosind un model de simulare a formării producţiei, Analele ICCPT Fundulea, LVIII, 21-40.