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MANAGEMENT OF WINTER CEREAL CROPS FROM SOWING TO FLOWERING – SCIENTIFIC AND ECONOMIC CONSIDERATIONS

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Abstract

Through this paper we aimed to show that, during a vegetative cycle, winter cereal must go through a physiological process of vernalization (low temperatures), which induces and controls flowering and fruiting, also regulating the following development stages. The research objective was to establish the vernalization model on 5 wheat and 2 barley winter varieties, in difficult climatic conditions, generated by water stress, lack of cold periods, but also by some technological aspects. Own research, observations and measurements were carried out in the experimental fields with varieties from south Romania (Modelu - Calarasi county), during the period 2012-2022.It was found that there are significant differences between varieties regarding the parameters required for vernalization, the development of which is genetically coordinated by genes that produce vernalin – the hormone that induces vernalization and which, modified by demethylation, forms gibberellic acid, subsequently participating in the development of the apex, of the spikelets, of the ear, pollinating anthers and soft grains. Uneven seedbed preparation work and sowing depth also create inequalities in water access to seeds, in the achievement of germination and vernalization.

Key words: *wheat, barley, vernalization, development stages, yield*

INTRODUCTION

Winter cereals (wheat, barley, oats) are crops that are sown in one year (autumn, usually in October-November) and harvested in the following year, in June-July.These coordinates are valid for areas with a temperate climate, category in which Romania is also included (Berca et al., 2021) [2].

In areas with small temperature differences between summer and winter and with humidity ensured at the near-optimal level of plant's (crop's) requirements, qualitative transformations in the genetic and hormonal system of the plant are reduced (Ciura& Kruk, 2018; El Sabagh et al., 2022) [4, 5].The need for vernalization is equally low (Pennington and Costa, 2020) [12]. Vernalization is a genetic-physiological process, specific to winter cereals, especially in temperate areas, with lower humidity, through which the plants, after going through a vegetative phase (from sowing to three leaves plants), to initiate the reproductive stage (flowering + fruiting) are forced to go through a cold period in order to receive permission to make flowers and seeds.

Vernalization is a process that occurs with different intensities depending on climatic conditions (Iqbal et al., 2022) [8].Where the average winter temperatures are above 10°C and humidity is ensured, cultivated varieties don't feel the need for an intense vernalization, at the opposite pole are the areas with harsh winters and very low temperatures. According to Fowler (2018) [6], which presents the results of research carried out on very dry soils, there is a correlation between the intensity of vernalization and the resistance of crops to low temperatures over winter.

Our own observations showed that this correlation also exists in the Romanian area, especially in the rustic varieties of cereals.

The same author (Fowler, 2018) [6] claims that in dry areas, the plants that will achieve yields close to their maximum potential are those that enter the winter at least in the three-leaf stage and, most likely, already having tillers. It is obvious that in this phase the wheat is already vernalized.
With lower intensity, vernalization can occur at earlier stages and even at the sprouting stage (Yan et al., 2015) [16]. The yields obtained in this case can be 10-40% lower. It is concluded that for frosty winters it is desirable for vernalization to take place in autumn, and for the reproductive stage to take place in spring. From the specialized literature (Brooking, 1996; Ottman et al., 2013; Streck et al., 2003) [3, 11, 13] the idea emerges that vernalization has significant effects at 2-10°C, with a significant decrease in intensity at temperatures above 11°Cand an obvious loss of its effects above 18°C.
Also, vernalization is genetically coordinated. The main wheat genes that are involved in the physiological process of vernalization are VRN1, VRN2 and, more recently, VRN3 and VRN4 (Hyles et al., 2020; Kiseleva & Salina, 2018; Li et al., 2021; Trevaskis et al., 2007) [7, 9, 10, 15]. According to Trevaskis (2015) [14], all genes concerned with germination-vernalization and flowering initiation are located on the long arm of chromosome 5.
Having all this information regarding the vernalization process, the proposed goal was to find correlations between the achievement of vernalization and the yields obtained in different varieties of cereals, under abiotic stress conditions.

MATERIALS AND METHODS

The research whose results are presented took place in the south part of Romania (Calarasi county), in harsh climatic conditions, and focused on the behaviour of winter cereals against vernalization and against the frost resistance of the selected varieties.
Observing changes in the vegetative, reproductive, but also productive behaviour of the wheat and barley plants belonging to the different varieties tested, the objectives were proposed and the working method was established.
To begin with, we wondered to what extent the climatic changes, announced as present in the area, influenced the vegetative and reproductive stage of some varieties.
The vegetative period is dominated by two extremely important processes, namely vernalization and frost resistance. Using sigmoidal functions, the quality of vernalization was studied as a function of the temperature factor, and functional corrections have been made when the amount of soil water was well below 50% of the AMI (active moisture interval) and could block vernalization.
Studies and correlations were made between the quality (intensity) of vernalization and the growth, development and productivity of wheat and barley plants.
The research continued by developing methods of growth and development during the breeding and maturity periods. The studies were carried out in the period 2012-2022 (10 agricultural years), in the experimental fields, the research lots and the fields for multiplying varieties belonging to the company Probstdorfer Saatzucht Romania SRL, in the area of Modelu, Calarasi county.
Research was carried out using the survey method in the territory, field photography, plant sampling, measurement of yields components, climate data and soil moisture. Five wheat varieties were analyzed annually, and if one of them was missing, it was replaced by another variety with similar characteristics.
The main varieties selected were Laurenzio, Maurizio, Tamino, Arnold and Monaco, and complementary Balaton, Bitop and Christoph. The two varieties of barley (Finola and Cremona) were included in the study in the last 5 years (2017-2022).
The platform on which the research was carried out is positioned above the Danube valley, on a slightly carbonated soil, with a neutral pH and a humus content of 2.78%. All climate data from the 10 years of research were compared with the multi-year average, whose reference interval is the period 1961-1990. Afterwards, graphs and tables were

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used to highlight the differences that appeared and to emphasize possible climate changes.

The calculations concerning the correlations between the days of vernalization and the obtained yields, as well as those between its intensity and the number of spikes/sqm, were statistically processed using the Table Curve 2D program.

RESULTS AND DISCUSSIONS

Regarding the local climatic conditions, the average sum of precipitation for 30 years (1961-1990, taken as the reference interval) was 473 mm and the average annual temperature was 11.7°C (Figure 1).The distribution of temperatures varied from -1°C in January to 22.7°C in July, i.e. an amplitude of 23.7°C, which indicates typical forest-steppe temperatures. Over this control interval, the monthly variation in precipitation was reduced. Two not common situations were encountered, namely:

(i)the average for the first 4 months and the last 4 months of the interval, so in 8 of the 12 months of the year, the precipitations were uniform, positioned between 40-45 mm;

(ii)during the experimental period (2012-2021 for climatic conditions), the average monthly amount of precipitation was 584.1 mm, i.e. 115 mm more than the 30-year average, placing the region in a forest transition zone.

The variation of the monthly average of temperatures was, in amplitude, greater than in the multiannual control average.

From this point of view, the difference is not great.

Very large is the monthly variation of precipitation each year. During the 10-year period (2012-2021) there were months, for example in the 2016-2017 agricultural year, where no mm of precipitation fell (December 2016 and January 2017) and numerous months in different years where less than 10 mm were registered.

Every year there were 2-4 months in this situation. Autumn and spring droughts were frequent and contributed to the significant reduction of both the induction of the vernalization process and the harvests obtained.

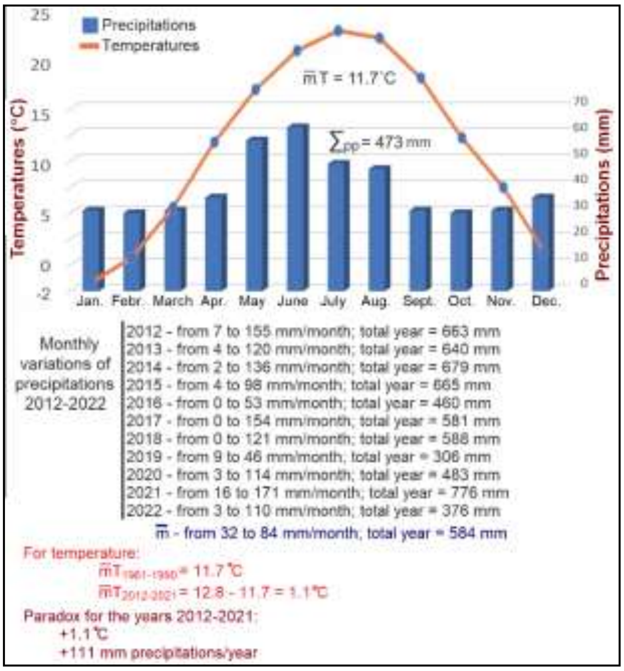

Fig. 1. The evolution of average monthly and annual temperatures and precipitation, for the period 1961-1990, completed with the interval 2012-2021
Source: Own processing after public and personal data.

Based on all these data, the paradox was reached according to which:

(a)the average annual temperature in the period 2012-2021 is 1.1°C higher than the multi-annual reference average;

(b)average annual precipitation is 111 mm higher than the control average.

If we accept the idea that there have been climate changes that have increased temperatures by 1.1°C in 10 years, i.e. 0.11°C/year, then the 111 mm/year increase in precipitation is no longer justified by climate change.

Given that December was rainy in 30% of cases, with precipitation over 100 mm, it is difficult to explain the continuous decrease of the soil water reserve, which in the years 2016-2021 influenced the quality of vernalization. At the same time, the temperatures over the winter were high enough to not be able to test the frost resistance of the studied wheat and barley varieties.

Table 1 lists the 10-year average temperatures of the four months (November-February) that could have contributed to the induction of vernalization (0 → 10°C).

Table 1. Average temperatures and precipitation in the months of vernalization and frost, 2012-2021

Crt.	Month	Average T (°C)	Average P (mm)
1.	**Nov.**	7.67	54.9
2.	**Dec.**	2.53	54.9
3.	**Jan.**	0.11	43.8
4.	**Febr.**	2.62	31.8

Source: Own determination.

It is found that the temperature factor was in optimal parameters, so from a biological point of view the vernalization process was possible. Water, which is the second absolutely necessary factor for vernalization, comes mostly from precipitation, and when the conditions are right, from vapor condensation on plants and in the topsoil. Crop vernalization models are very numerous, depending on the diversity of climatic conditions, but also on the studied varieties.

Among the many possibilities of grain vernalization, our own studies and calculations led to the detection of three models that were the most common in the research and observations from Modelu (Călăraşi county), as shown in Figure 2.

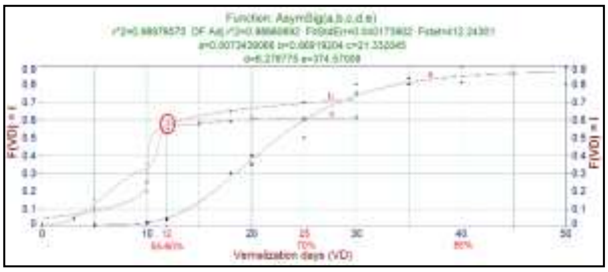

Fig. 2. Vernalization intensity – average for wheat and barley varieties, under different conditions offered by the autumn months from 2012-2022
Source: Own determination.

Model 1 – the years 2012, 2013, 2015, 2021 and 2022 had, in the autumn period (the months of November and December), enough water to ensure a humidity suitable for the demands of vernalization, and the temperatures were also optimal. Vernalization had a slow evolution, in the form of a wide sigmoid (curve "a" in Figure 2). At 25 days the process reached 60% of the intensity, at 30 days it had reached 72%, and around 40 days it ended, with a yield of about 85%. In all these years, the average production of the varieties was between 5,000-6,500 kg/ha, depending on the evolution of the vegetation factors from spring until the formation of the ear.

Model 2 – the years 2014, 2016, 2017 and 2018 had temperatures favorable to vernalization as early as autumn, and consistent rain fell in November (58 mm in 2014, 74 mm in 2016, 154 mm in 2017 and 64 mm in 2018).Under these conditions, vernalization took place more quickly. After 12 days from emergence, the rapid vernalization phase (3 leaves) was reached, and the process reached 55-60%(curve "b" in Figure 2). The maximum was achieved at 25 days, reaching approximately 70%.

Model 3 – was also the shortest and occurred at the end of winter 2020, after a severe fall and winter drought. Rains in December 2020 (114 mm) allowed the plants to germinate, thanks to positive temperatures in January and February (2 and 6°C respectively). Vernalization took place in a few days, after 12 days from sunrise it had achieved 55% of its activity, and after 18 days it reached 60% (curve "c" in Figure 2). More couldn't be achieved, also correlated with the drought that followed in spring and early summer. Vernalization couldn't achieve its goal of initiating flowering and driving the crop toward reproduction and production. Yields were close to zero, with one exception – the Bitop variety, which obtained 3,165 kg/ha. It is quite possible that this cultivar may have vernalized better and/or had greater drought tolerance.

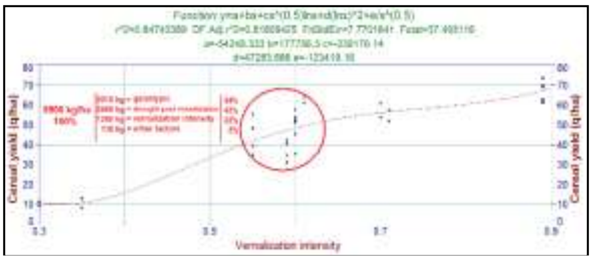

Fig. 3. The correlation between the intensity of vernalization and the obtained yields in wheat and barley (10-year average)
Source: Own determination.

Starting from the three models, the question arises whether the intensity, the volume of the vernalization process is correlated with the production. Taking into account the large time gap between vernalization and maturity and the large number of intervening factors, whether natural or anthropogenic, this correlation shouldn't exist. The continuity of some negative or positive factors, both for vernalization and for yields, make this correlation possible, at least in the studied varieties (Figure 3).

The correlation ratio of the function is $r^2 = 0.847$, and the function is logarithmic, slightly asymmetric. The difference in yields between the years with the least vernalization and those with the best vernalization was, on average, 5,900 kg/ha. Although, statistically, this difference is very significant, we cannot attribute it entirely to vernalization. From the moment of vernalization to maturity, a minimum of 150 days passed, during which the biotic and abiotic factors were extremely variable.

The calculation of the influence of the factors was carried out, according to the methodology proposed by Berca and Draghici (1972) [1]. It turned out that vernalization could have an influence of 22% (±5%).The main factors that created variations in the statistical system studied were genotype, with 34%, and post-vernalization drought (42%).

Among the selected varieties, the biggest variation for the three studied factors is the Maurizio variety, which in good vegetation conditions produced 6,111 kg/ha (year 2021), and against the background of weak vernalization and droughts in the spring, it had a yield of only 930 kg/ha (year 2020).The Bitop and Laurenzio varieties had a better production stability, with smaller variations generated by the studied factors.

It should be emphasized that when the vernalization of the field is below 50%, followed by severe droughts in winter-spring, as happened in the agricultural year 2019-2020, the grain production cannot exceed 3,000 kg/ha. Figure 4 shows the correlation between the intensity of vernalization and the density of the crop, i.e. ears/sqm. Based on the information collected from the field, it appeared that vernalization leads to the initiation of flowering, and it was evident that at higher indices of vernalization, we have more ears, which can lead to a higher yield.

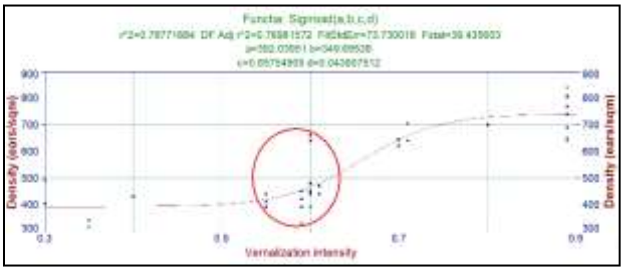

Fig. 4. The correlation between the intensity of vernalization and the density of ears/sqm
Source: Own determination.

At a vernalization below 50% there are problems with full initiation of flowering. If vernalization is sufficient, 70-90%, complete reproductive organs are formed, but a significant number of flowers disappear if the months of February-April are very dry. Sometimes numerous ears may form, but they will not always be full of grain. Also, the brothers dry up or end up forming small ears, insignificant for the productivity of the plants and of the crop, as a whole.

CONCLUSIONS

Autumn wheat and barley varieties cultivated in the arid area of the Romanian Plain, in order to produce flowers and fruits, the main elements of production, are obliged to go through the physiological phase of vernalization.

Vernalization can be done in early winter, after the cereal seedlings have reached the three-leaf stage. The process takes place rapidly at temperatures of 0 → 10°C, more slowly at temperatures of -5 → 0°C and +10 → +15°C, and outside these ranges it doesn't take place at all. The studies carried out in a period of 10 agricultural years (2012-2022) showed the existence of three vernalization models, which were differentiated according to the water and air regime of the soil (maximum at 75% AMI and 0-10°C).

Vernalization took place between November and February, being able to intervene at any time when the requirements for temperature and humidity were met.

In conclusion, the vernalization period was different, depending on the climatic and agrotechnical conditions. Monitoring the vernalization process in the field will need to be part of cereal crop management.

The uniformity and intensity of the process are significantly influenced by the quality of the germination bed, the uniformity of the land during sowing, the conservation of moisture and the quality of the seeds. The seeds of the barley cultivars germinated faster and had a shorter vernalization period. The correct management of vernalization, under the given conditions, can lead to the reduction of the duration of the vernalization phase, to the uniform induction of flowering, to obtaining more uniform and higher yields and to a profitability of about 5-15% higher.

The processes of vernalization, resistance to frost and induction of flowering are genetically coordinated by the VRN gene complex, which throughout the vegetation periods induced the specific phytohormones, which through particular genetic processes (activation, inhibition, disappearance) allowed the unfolding physiological mechanisms during the entire period of vegetation and crop reproduction. These mechanisms were disturbed during periods of prolonged droughts, which led to the decrease of growth and production indices and to the reduction of yield and its quality, as happened in the year 2020, in particular.

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