Research on the influence of genotype – growing conditions interaction on yield and quality of facultative wheat

(SUMMARY OF Ph.D. THESIS)

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INTRODUCTION

Compared to the current situation, following the research of OLESEN et al. (2011) and VALIZADEH et al. (2014), it concluded that the period of wheat cultivation, in all scenarios of climate change, will be reduced. Possible reasons are the increase in the temperature and the acceleration of the wheat growth stages.

Also in 2016, BING et al. demonstrated that an overall temperature increase of 1^0C would lead to an overall decrease in wheat production by 4.1-6.4%. Currently, more than 700 million tons of wheat are produced annually, which is transformed into various products for human consumption, including bread flour, pasta, cakes, breakfast cereals and more. A reduction of only 5% in production would lead to a loss of around 35 million tonnes each year.

To reduce these risks, the impact of climate change mitigation strategies and management systems for adapting crops to climate change conditions should be considered.

In this context, in our research we followed the behavior of three facultative wheat genotypes (Taisa, Ciprian, Lennox), compared to three winter wheat genotypes (Arieşan, Andrada, Codru) and three spring wheat (Pădureni, Granny, Triso), to which a technology readily available to farmers in Transylvania was applied. The research included 5 experiences, corresponding to the 5 sowing dates of facultative wheat. Each experience had 3 levels of fertilization, the application of fertilizers being done in installments.

STRUCTURE OF THE WORK

The doctoral thesis entitled "Research on the influence of genotype - growing conditions interaction on yield and quality of facultative wheat" is structured in 8 chapters and includes 152 pages, 53 tables, 96 figures and 166 bibliographic titles from the latest years of national and international literature. It is structured in two main parts, the literature review and personal contribution.

The first part presents the current state of knowledge and is divided into 2 chapters. It has 26 pages.

The second part contains 103 pages and represents the personal contribution. It is structured in 6 chapters and contains the methodology and results of research conducted in 2018-2020.

PURPOSE AND OBJECTIVES OF THE RESEARCH

The purpose of this doctoral study is to develop the technology of facultative wheat crop in Transylvania, as an alternative in the context of climate change.

The specific objectives of the research that led to the achievement of the purpose are:

- Identifying an optimal sowing date for facultative wheat;
- Evaluating the yields of the facultative wheat varieties studied under the influence of the climatic conditions, of the sowing date, of the fertilization; comparing them with the yields of some winter / spring varieties, local and foreign;

- Evaluating the physical and quality indices (protein, thousand kernel weight, test weight) of the facultative wheat varieties studied under the influence of the climatic conditions, of the sowing date, of the fertilization; comparing their protein content with that of some winter / spring varieties, local and foreign;
- Determining the parameters of variability for the morpho-productive characters of the studied facultative wheat varieties.

MATERIAL AND METHOD

In order to achieve the proposed objectives, during 3 years (2018, 2019, 2020) a multifactorial experience was organized, type A x B x C. The research included 5 experiences corresponding to the 5 sowing dates of facultative wheat (three sowing dates in autumn, two in spring) and 3 sowing dates for the winter wheat genotypes and two sowing dates for the spring wheat genotypes. The research included the following experimental factors:

- Sowing date (table 1) – with 5 graduations (3 sowing dates in autumn and 2 in spring).

Table 1

Sowing date

Sowing date / Year	Autumn			Spring	
	I	II	III	IV	V
2017-2018	10.10.'17	02.11.'17	06.12.'17	15.03.'18	04.04.'18
2018-2019	10.10.'18	30.10.'18	16.11.'18	04.03.'19	18.03.'19
2019-2020	11.10.'19	06.11.'19	26.11.'19	04.03.'20	18.03.'20

- Fertilization – with 3 graduations:
  $F_1 = N_{36}P_{92}K_0$ kg ha^{-1} s.a. - applied in autumn, before sowing;
  $F_2 = N_{72}P_{92}K_0$ kg ha^{-1} s.a. – applied before heading;
  $F_3 = N_{105}P_{92}K_0$ kg/ha s.a. - applied before heading.
- Genotype – with 6 graduations:

Autumn sowing dates:	Spring sowing dates:
S_1 - Arieşan (winter);	S_1 – Pădureni (spring)
S_2 – Andrada (winter);	S_2 – Granny (spring)
S_3 – Codru (winter);	S_3 – Triso (spring)
S_4 – Taisa (facultative);	S_4 – Taisa (facultative)
S_5 – Ciprian (facultative);	S_5 – Ciprian (facultative)
S_6 – Lennox (facultative)	S_6 – Lennox (facultative)

The experiences were laid out by using the subdivided split plot design with three replications.

RESULTS AND DISCUSSIONS

Results of research regarding the grain yield

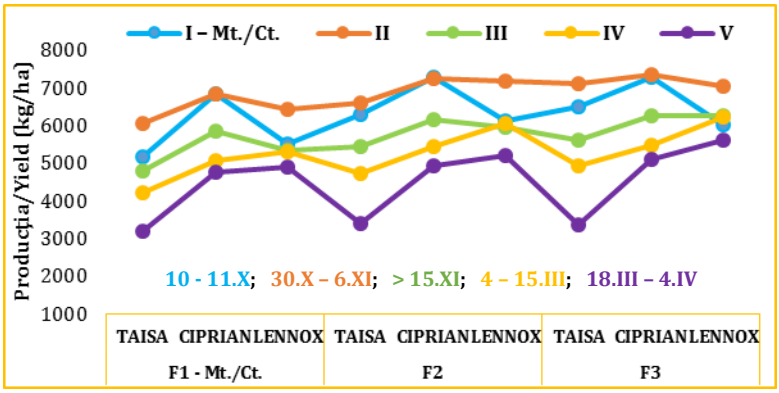
The Taisa variety obtained the highest yield (7272 kg ha^{-1}) in 2018, when it was sown in the sowing date II and on the level of fertilization F_3 ($P_{92}N_{105}$), very close to that of the winter wheat Codru variety (7280 kg ha^{-1}), which was the most productive.

Ciprian had the best production -7343 kg ha^{-1} - in the sowing date II at the fertilization with $P_{92}N_{105}$, but it is very well suited in the conditions of the sowing date I, with the same dose of fertilizers, the production obtained being 7274 kg ha^{-1}.

Lennox achieved the best yields in the conditions of sowing date II, in the fertilization with $P_{92}N_{72}$, these reaching average values of 7163 kg ha^{-1}. It is important to note that this variety, in all autumn sowing dates, had no higher yields at the level of fertilization F_3, compared to F_2, which means that it makes better use of the nitrogen left in the soil by the previous plant, respectively pea for beans.

In the sowing date III, after November 15, compared to the sowing date I, the yield decreased very significantly in both Taisa (with 373 - 885 kg ha^{-1}) and Ciprian (with 969 - 1102 kg ha^{-1}), with the exception of Lennox , which even recorded an increase of 392 kg ha^{-1} (***). In the case of the Lennox variety, a better behavior was observed in the sowing date III, compared to the 1st one (I), this probably due to the fact that by late sowing in autumn it manages to avoid the attack of cicadas that transmit the wheat dwarf virus.

Sown in spring, the studied facultative varieties had the best yields in the sowing date I on the level of fertilization F_3. The average yields reached values of 4923 kg ha^{-1} at Taisa, 5474 kg ha^{-1} at Ciprian and 6220 kg ha^{-1} at Lennox.



E x F x S: LSD 5% = 302; LSD 1% = 402; LSD 0.1% = 522;
F x E x S: LSD 5% = 316; LSD 1% = 418; LSD 0.1% = 542;

Fig. 1 The average yields of facultative wheat genotypes according to the sowing date and nitrogen fertilization

Figures 2, 3 and 4 show, for each studied facultative variety, the link established between yield and the length of growing season. The calculated correlation coefficients indicate the existence of a very significant relationship between theme (r =0.684*** - Taisa, r =0.781*** - Ciprian, r =0.235*** -Lennox; GL=133; α 0.1% = 0.208- https://www.statisticssolutions.com/table-of-critical-values-pearson-correlation/).

For the Taisa variety, the calculated coefficient of determination (R^2 = 0.477) shows that the variation of grain yield is due to the length of growing season in proportion of 47.7%. The highest value of this coefficient of determination was registered for the Ciprian variety (R^2 = 0.6415), and the lowest for the Lennox variety (R^2 = 0.0825).

In the case of Taisa, the high value of the regression coefficient (b = 51.151) indicates a close relationship between yield and the length of growing season, demonstrating the need for a larger number of days than the other varieties in order to express its yield potential (fig. 2).

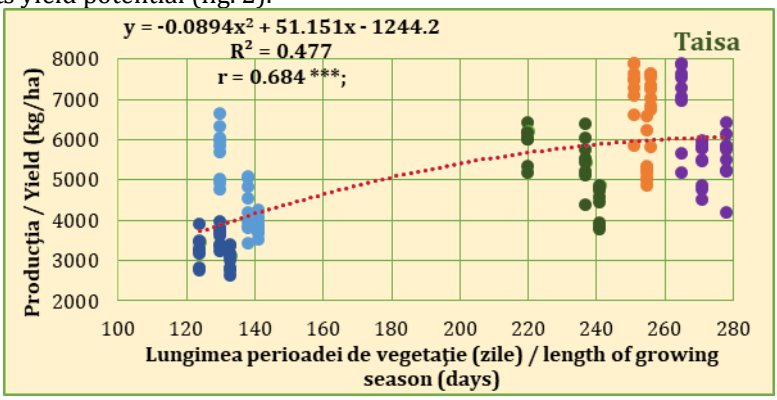


Fig. 2 The relationship between length of growing season and yield for Taisa genotype

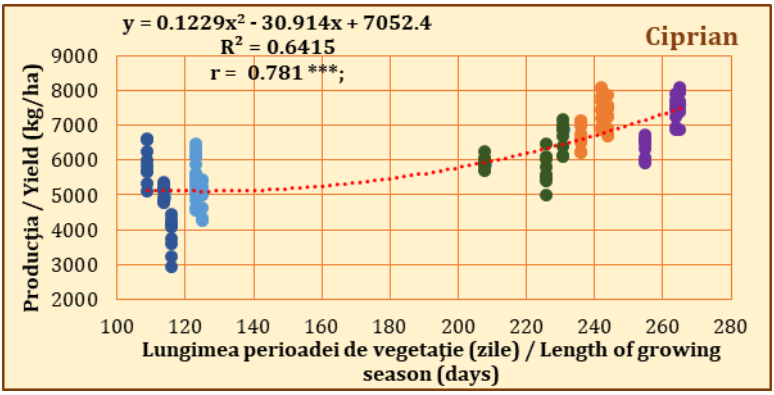


Fig. 3 The relationship between length of growing season and yield for Ciprian genotype

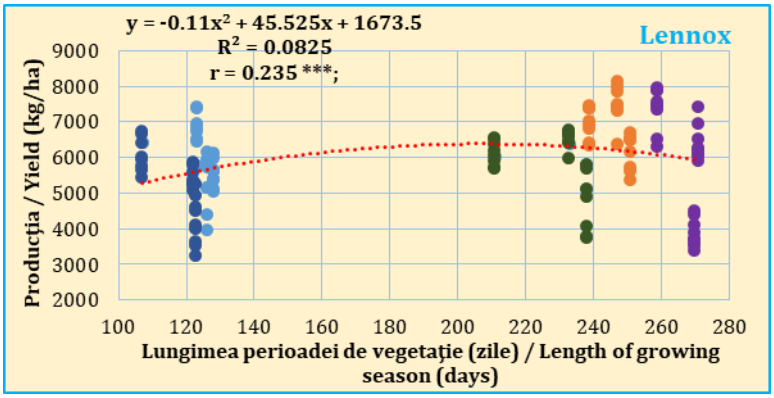


Fig. 4 The relationship between length of growing season and yield for Lennox genotype

Research results on protein content

Taisa had the highest percentage of protein in spring sowing conditions, in the sowing date IV, in F_3 - 15.09%; Ciprian obtained the maximum value of 15.77% protein in spring (sowing date V), on level 3 of fertilization, and Lennox had the highest protein content in the sowing date III from autumn, on the highest fertilization level - 14.08% (table 1).

Table 1

The influence of E x F x S interaction on facultative wheat varieties protein content

Fertilizer doses	Genotype	Protein (%)				
		I – Mt./Ct (10-11.X)	II (30.X-6.XI)	III (> 15.XI)	IV (4 – 15.III)	V (18.III-4.IV)
F_1 ($P_{92}N_{36}$)	TAISA	10.34	11.67***	11.83***	13.33***	13.11***
	CIPRIAN	10.14	10.51^{NS}	12.04***	12.99***	13.02***
	LENNOX	10.14	10.03^{NS}	11.41***	11.78***	11.90***
F_2 ($P_{92}N_{72}$)	TAISA	11.36	12.29***	12.78***	14.48***	14.16***
	CIPRIAN	12.31	12.67^{NS}	13.86***	14.80***	14.87***
	LENNOX	11.46	11.79^{NS}	12.69***	13.31***	13.47***
F_3 ($P_{92}N_{105}$)	TAISA	12.51	13.24**	14.01***	**15.09*** **	14.89***
	CIPRIAN	13.89	14.26^{NS}	15.44***	15.68***	**15.77*** **
	LENNOX	12.86	13.29^{NS}	**14.08*** **	13.93***	13.99***
LSD 5% = 0.46; LSD 1% = 0.61; LSD 0.1% = 0.80;						

Qualitatively, Ciprian (facultative wheat variety) had the closest value of the protein content to the Arieşan (winter wheat variety), which is maintained in the breeding field of SCDA Turda as a quality control.

Sown in spring, Ciprian (facultative wheat variety) had an average protein content of 14.50%, very close to Pădureni (spring wheat variety) - 14.46%.

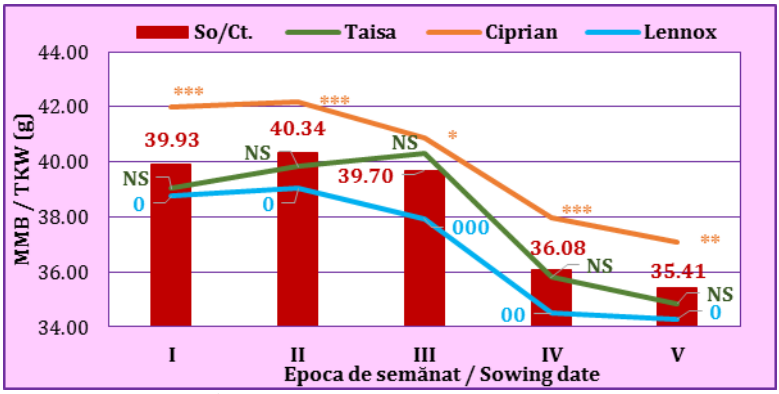
Table 2

Protein content of facultative and winter/spring wheat varieties in period 2018-2020

Symbol	Sown in autumn			Sown in spring		
	Genotype	Protein (%)	Duncan's Ranking	Genotype	Protein (%)	Duncan's Ranking
S_0	*Average of genotypes*	12.32	-	*Average of genotypes*	13.66	-
S_1	ARIEŞAN	13.19	*a*	PĂDURENI	14.46	*a*
S_2	ANDRADA	11.87	*d*	GRANNY	12.60	*d*
S_3	CODRU	11.87	*d*	TRISO	13.18	*c*
S_4	TAISA	12.23	*c*	TAISA	14.18	*b*
S_5	CIPRIAN	12.79	*b*	CIPRIAN	14.50	*a*
S_6	LENNOX	11.97	*d*	LENNOX	13.06	*c*
	LSD 5% = 0.11; LSD 1% = 0.14; LSD 0.1% = 0.18.			**LSD 5% = 0.12; LSD 1% = 0.16; LSD 0.1% = 0.20.**		
	DS 5% = 0.11-0.12.			**DS 5% = 0.12-0.14.**		

Research results on thousand kernel weight

The lowest values of TKW were obtained in the spring sowing dates, to all facultative wheat varieties, being associated with a shorter growing season, the expression of this character being limited by climatic conditions such as drought that occurs during of filling the grains, but also by the rains from the last part of the wheat vegetation that favor especially the attack of diseases (fig. 5).

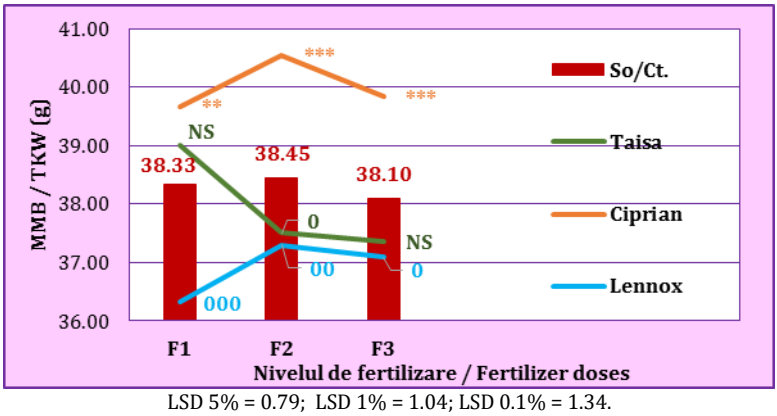


LSD 5% = 1.02; LSD 1% = 1.34; LSD 0.1% = 1.73.

Fig. 5 The influence of S x E interaction on facultative wheat varietes TKW

Additional fertilization resulted in a decrease in TKW of Taisa, from 39.01 g in F_1 to 37.37 g in F_3, and this could be attributed to the causal link between long growth cycle-later heading time and additional fertilization, which results in a prolongation of growing season, but a shortening of the phenophase of growth and filling of the grains, thus affecting their filling (fig. 6).

The TKW of Ciprian and Lennox varieties had the best average values at fertilization with $P_{92}N_{72}$ (F_2); it was between 39.67 and 40.54 g in the case of the Ciprian variety and between 36.32 and 37.30 g in the case of the Lennox variety.



LSD 5% = 0.79; LSD 1% = 1.04; LSD 0.1% = 1.34.

Fig. 6 The influence of S x F interaction on facultative wheat varietes TKW

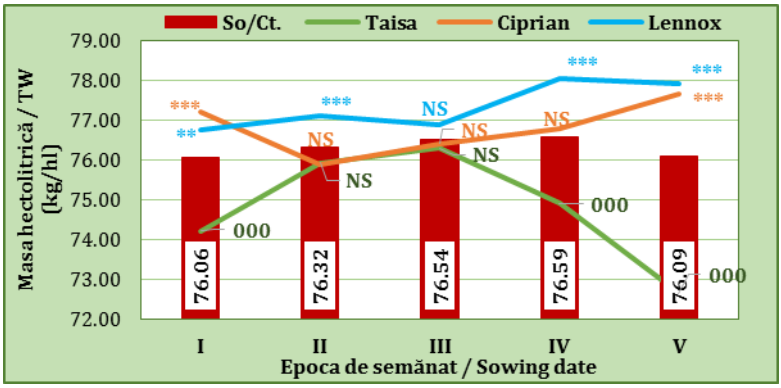
Research results on test weight

Depending on the sowing date, the test weight of Taisa varied between 72.66 (sowing date V) and 76.31 kg/hl (sowing date III), the lowest values being obtained in the spring sowing dates, which limits the achievement of the yield potential (fig. 7).

Ciprian obtained the best values of the test weight in sowing dates I (77.21kg / hl) and V (77.68 kg / hl), but the lowest value by 75.91 kg/hl was registered in sowing date III.

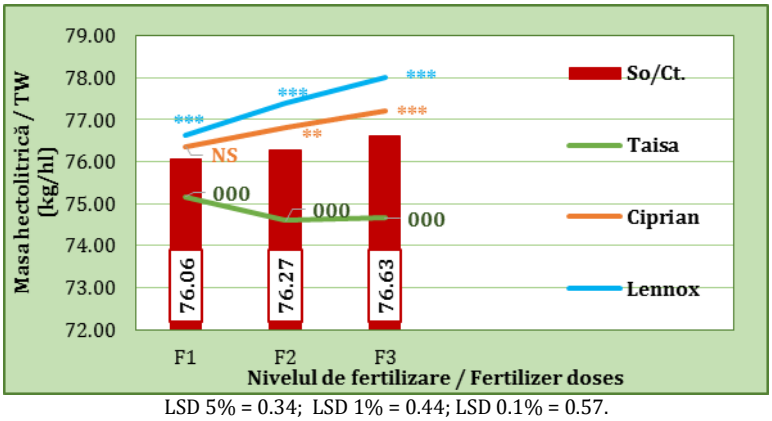
Lennox has distinguished itself by obtaining higher values of test weight, especially in the spring, exceeding 78 kg/hl, the advantage of this facultative variety being better grain filling.

Increasing the nitrogen doses (fig. 8), the growing season of Taisa was prolonged, registering a higher incidence of the phenophases of growth and filling of the grains with the dry periods, so that the filling of the grains was defective; this was reflected in the values of the test weight which decreased from 75.17 kg/hl (F_1) to 74.6 (F_2) kg/hl, while in the Ciprian variety it increased from 76.37 kg/hl (F_1) to 77.22 kg/hl (F_3) , and at Lennox from 76.64 kg/hl (F_1) to 78.01 kg/hl (F_3).



LSD 5% = 0.43; LSD 1% = 0.57; LSD 0.1% = 0.74.

Fig. 7 The influence of S x E interaction on facultative wheat varietes test weight



LSD 5% = 0.34; LSD 1% = 0.44; LSD 0.1% = 0.57.

Fig. 8 The influence of S x F interaction on facultative wheat varietes test weight

CONCLUSIONS AND RECOMMENDATIONS

Conclusions on the influence of sowing date and fertilization on yield of facultative wheat

For the facultative wheat varieties: Taisa, Ciprian and Lennox, the best yield results, in the three years of study, were obtained in the sowing date II from autumn, which coincided with the period October 30-November 6.

In autumn sowing conditions, the yield results obtained show that there are not very big differences between the facultative varieties regarding the yield potential, but a slight superiority of Ciprian given by the precocity and the presence of the plum layer (that gives it resistance to attack of cicadas that spread the wheat dwarf virus) must be admitted..

By delaying the sowing in spring, yield losses were obtained; these varied depending on the level of fertilization between 318 and 519 kg ha^{-1} in Ciprian, between 420 and 604 kg ha^{-1} in Lenox and reached high levels in Taisa (1038 - 1559 kg ha^{-1}).

In 2018, in sowing dates I and II, the yields of the facultative varieties Taisa (7001-7244 kg ha^{-1}) and Lennox (7366-7000 kg ha^{-1}) were close to those of winter varietes, Codru (7158-7323 kg ha^{-1}) and Andrada (6977-7130 kg ha^{-1}).

The differentiated behavior of facultative wheat varieties, depending on the sowing date and the level of fertilization, showed that a specific cultivation technology must be developed for each of them; the highest yields were obtained for Taisa when it was sown in sowing date II and on the level of fertilization F_3 (7108 kg ha^{-1}), for Ciprian in sowing date II and F_3 (7343 kg ha^{-1}), and for Lennox in sowing date II and F_2 (7163 kg ha^{-1}).

The yield results obtained for the facultative wheat varieties in the spring sowing conditions were close to those of the spring varieties, highlighting at the same time the fact that there are differences between them in the vernalization stage and implicitly their inclination towards autumn or spring. .

The long growth cycle of Taisa determined by the fact that it requires a greater number of days for the vernalization stage shows that it has a inclination towards autumn, and in the spring sowing conditions it achieves better yields than Pădureni, a spring variety, only if it is sown very early.

Conclusions on the influence of sowing date and fertilization on physical and quality indices of facultative wheat

In the facultative varieties, the percentage of protein increased in the late autumn sowing dates and reached maximum values in the spring sowing conditions, so that the average value of the protein content varied between 11.4 (sowing date I) and 14.3 (sowing date IV)% at Taisa, between 12.11 (sowing date I) and 14.55 (sowing date V)% at Ciprian and between 11.49 (sowing date I) and 13.12 (sowing date V)% at Lennox.

The nitrogen fertilization applied before heading was beneficial for the quality of the studied wheat varieties, leading to an increase in grain protein content from 12.06% (F_1) to 13.95% (F_3) for Taisa, from 11.72% (F_1) to 15.01% (F_3) for Ciprian and from 11.05% (F_1) to 13.63% (F_3) for Lennox.

According to the classification of the quality of wheat for bread according to the protein content of the grains, the facultative varieties taken into study meet the conditions of a good quality (11.6 - 13.5% protein) for fertilization with $P_{92}N_{72}$ (F_2) and a very good quality (13.6 - 15.5% protein) upon fertilization with $P_{92}N_{105}$.

Depending on the sowing date, the limits of variation for the TKW were between 34.84 g (sowing date V) and 40.29 g (sowing date III) at Taisa, 37.08 g (sowing date V) and 42.16 g (sowing date II) at Ciprian and between 34.30 g (sowing date V) and 39.04 g (sowing date II) at Lennox.

The studied facultative varieties had the following maximum values of TKW: Taisa - 41.51g (sowing date III, F_1), Ciprian - 43.39g (sowing date II, F_2) and Lennox - 39.77g (sowing date II, F_2).

Duncan's ranking classified sowing dates III and IV as the best for obtaining a distinctly higher test weight than the control (sowing date I), reaching values of 76.54 - 76.59 kg/hl. The sowing date II was ranked second, with an average test weight of 76.32 kg/hl.

Applying additional fertilization ($P_{92}N_{105}$), the test weight increased very significantly compared to the basic one, by about 0.57 kg/hl.

Conclusions on variability of morpho-productive characters of facultative wheat

For each facultative variety, the standard deviation for the studied characters shows higher values in the late sowing date, outside the optimal one, in which there are less favorable conditions, which limit the expression of the yield potential.

The studied facultative varieties are endowed with elements of productivity through which they can express their yield potential, being limited, however, by the appearance of surprising environmental conditions or by the attack of some diseases and pests.

Taisa is distinguished by: large number of spikelets/spike (> 20), large number of grains in spike (41-50) and grain weight/spike (1.64 - 1.75g). Achieving productivity potential is limited by climatic factors, especially in the spring, when lack of rainfall causes poor grain filling, resulting in a low TKW. Direct relations are established between the main elements of productivity: the number of fertile tillers/plant and TKW (r = +0.845*), TKW and yield (r = +0.921**), the number of fertile tillers/plant and yield (r = +0.986***), but also a negative correlation such as that between the number of grains/spike and TKW ($r = -0.940^{00}$).

Ciprian is highlighted by a large number of grains/spike (42-43) and a TKW > 42 g in the autumn sowing conditions. The relationships established between the main productivity elements are indicated by the value of the calculated correlation coefficients. Positive correlations were reported between TKW and the number of fertile tillers/plant (r = +0.956**), TKW and yield (r = +0.899**) and between the number of fertile tillers/plant and yield (r = +0.969***). Negative correlations were determined for this variety between the number of grains/spike with the number of fertile tillers/plant (r = -0.831) and with the yield (r = -0.862).

Lennox, in harsh conditions, compensates by increasing the number of grains /spike (42 - 49), the weight of grains/spike (> 1.6 g), emphasizing that it maintains a relatively constant number of fertile tillers/plant (≈2) . For this variety, the main role in reaching yields close to the potential of the genotype is attributed to the number of fertile tillers/plant, reflected by the value of the correlation coefficient r = 0.969***.

Recommendations

According to the particularities of the studied facultative wheat varieties that have been highlighted as a result of the research carried out, the technological

recommendations will be specific, with the mention that certified and treated seed will be used for sowing.

TAISA

- it is a genotype with a long growth cycle, with a inclination towards autumn, with medium winter hardiness, which requires a higher number of days with low temperatures for vernalization**;**

- optimal sowing date: in autumn is between October 25 and November 10; the winter windows from December, January and February, and in the spring until March 15;
- optimal fertilization: $P_{90}N_{110}$ kg s.a., ensuring a ratio between N and P of 1.2: 1;
- the fertilization will be done in fractions, in two stages: the whole dose of phosphorus and ½ from the dose of nitrogen before sowing or at sowing time and ½ from the dose of nitrogen from the stem elongation to the booting;
- sowing density: 550 g.g./sqm, distance between rows 12.5 cm;
- outside the optimal sowing date (late autumn and spring), we recommend a 10% increase in the seed rate, ensuring 600 g.g./sqm;
- in the case of herbicides, products containing the active substances of the Sekator product should be avoided, as a sensitivity to it has been observed;
- for diseases and pests, two phytosanitary treatments are recommended, the first with the herbicide, and the second before heading. In years with hot and rainy summers, it is recommended to carry out an additional phytosanitary treatment to combat fusariosis;
- recommended cultivation area: northern Transylvania (Cluj, Sălaj, Alba, Mureş), northern Moldova (Suceava, Botoşani, Neamţ, Iaşi, Vaslui).

CIPRIAN

- it is an early variety, with good winter hardiness, low requirements for vernalization;
- optimal sowing time: in autumn is between October 10 and November 10; in spring is between March 1 and 31;
-optimal fertilization: $P_{90}N_{110}$ kg s.a., ensuring a ratio between N and P of 1.2: 1;
- the fertilization will be done in fractions, in two stages as in Taisa;
- sowing density: 550 g.g./sqm, distance between rows 12.5 cm;
- in the spring we recommend a 10% increase in the seed rate;
- two phytosanitary treatments on vegetation are recommended, the 1st with the herbicide, and the 2nd before heading;
- recommended culture area: it is wider, including the West of the country (Bihor, Timiş, Arad, Satu Mare) in addition to all the counties in Transylvania and Moldova;
- the harvesting will be done at the optimal time to avoid the losses caused by shaking.

LENNOX

- it is a semi-late variety, sensitive to winter frost in the absence of snow, low requirements for vernalization;
- optimal sowing time: in autumn is between October 25 and November 10; in spring is between March 1 and 31;
- optimal fertilization: $P_{90}N_{90}$ kg s.a., ensuring a ratio between N and P of 1:1;
- the fertilization will be done in fractions, in two stages: the whole dose of phosphorus and ½ from the dose of nitrogen before sowing or at sowing time and ½ from the dose of nitrogen from the stem elongation to the booting;
- sowing density: 550 g.g./sqm, distance between rows 12.5 cm;

- it is a variety sensitive to dwarf virus, therefore, in autumn, when the climatic conditions are favorable for cicadas and aphids, it is recommended to carry out a phytosanitary treatment with insecticide;
- recommended cultivation area: it is wider, including the west of the country (Bihor, Timiș, Arad, Satu Mare), near the counties of Transylvania and Moldova, but being a variety without edges is not indicated in areas where wild boar attack occurs.

Originalitatea și contribuţiile inovative ale tezei

The originality of the thesis consists in: the studied material – facultative wheat, less known in our country, and in the approach of experiences - five sowing dates, of which three in autumn and two in spring, staggered according to the optimal time of sowing for winter wheat and the optimal time for spring wheat, establishing the optimal time for sowing for each facultative variety, studied in both autumn and spring sowing.

An analysis of the variability of the morpho-productive elements according to the sowing date was performed and the productivity elements were identified by which each facultative variety studied stands out: number and weight of grains/spike in Taisa, number of grains/spike and TKW in Ciprian, the number and weight of grains /spike and the number of fertile tillers/plant in Lennox.

The obtained results allowed the elaboration of the cultivation technologies specific to each facultative variety, adapted for the climatic conditions of Transylvania.

Among the facultative varieties studied, Ciprian stood out as having a special plasticity, managing to ensure good quality productions regardless of the time of sowing, autumn or spring.

In the conditions of climate change, but also for financial reasons, the cultivation of facultative wheat comes to aid the farmers, first of all through the longer interval of the period in which it can be sown, thus contributing to the increase of the wheat cultivation area.

Facultative wheat can be introduced into crops that include late harvest crops such as corn or beets and, regardless of whether the seeds from crops sown in autumn or spring, can be used at any time of sowing, autumn or spring.

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