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INFLUENCE OF SOWING TIME ON THE PRODUCTION AND PRODUCTIVITY ELEMENTS OF WINTER WHEAT IN SOUTHERN ROMANIA

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Abstract

Wheat production is given by the possibilities of optimizing the interaction between ecological, technological and economic factors. The final production and quality of wheat is affected by pedoclimatic conditions and can be optimized and stabilized by respecting the sowing date associated with other important technological links. In general, the efficient strategy for obtaining maximum production is established by knowing the characteristics of the variety and the optimal time for applying technological highlights, and these must be adapted to the crop area. This article presents the results of research showing the effect of sowing time on the production and quality of winter wheat grains. Shifting the sowing time to an early date (September 25) or a late date (November 1) results in reduced yields. The results revealed that wheat planted on October-10 and October-25 produced higher spike length, 1000-grain weight, plant height and grain yield with a comparable number of tillers and number of grains per spike. It is recommended to plant wheat between October-10 to October-25 to attain higher grain yield.

Key words*: wheat, sowing times, variety, production.*

INTRODUCTION

Wheats genetic production potential of varieties is directly influenced by the relationship between precipitation and other technological links, and the final harvest is varied depending on the sowing period. The availability of water in the soil, the variety's resistance to drought, and the technological connections used at critical times are all closely related to the quick and consistent emergence of wheat seeds and the development of the crop under favourable conditions (Iagaru, 1998; Lupu, 2001; Popa, 2003). Prior studies on how climate and sowing time affect winter wheat production capacity have demonstrated the importance of technological links and their substantial impact on crop evolution (Epplin and Peeper, 1998; Tack et al., 2015). Several studies have underscored the importance and considerable effect of sowing time and plant density on the growth and progression of wheat crops, taking into account different climatic factors like precipitation and temperature (Raza et al., 2019).

Sowing time is a very important technological link to maximize yield and harvest quality, which is why research has primarily focused on the response of wheat crop to sowing at different times associated with technological factors (Paraschivu et al., 2017; Abendroth et al., 2017). The optimal sowing time for wheat crops in favorable conditions may vary across different agricultural regions, influenced by soil type and the fluctuations in soil moisture over time (Donatelli et al., 2012; Partal & Paraschivu, 2020). Wheat seeds need adequate soil moisture and favorable temperatures to germinate and establish properly in the early growth stages (Abendroth et al., 2017). Late sowing has become a common practice among farmers, as positive temperatures are often recorded during this period (Partal and Paraschivu, 2020). Depending on the crop area, early sowing leads to a higher number of spikes/square meter, heavier grains and a good yield, while late sowing negatively affected these characters (Wajid et al., 2006). Sowing at the optimal period leads to increased yields and avoids unjustified delay in seed germination and increased premises for inadequate quality. Under early sowing conditions, seeds are able to absorb water, which promotes rapid germination and quick plant growth, along with early branching (Donatelli et al., 2012;

Abendroth et al., 2017). The amount and distribution of precipitation, the soil's ability to retain water, along with plant variety and density, directly affect the crop's active growth period in both autumn and spring (Lobell and Burke, 2008; Raza et al., 2019).

Sowing date has a significant impact on growth stages, especially in the autumn period when temperatures are high and thus allow early sown wheat to grow and produce more wheels than later sown wheat (White & Edwards, 2008).Variations in final yield and grain quality among varieties are determined by their genetic characteristics, environmental conditions, soil nutrient levels and the technological methods used in crop management (Theago et al., 2014; Partal & Paraschivu, 2020). As the global population explosion progresses, more food, energy and goods are needed (Bonciu, 2023). The problem is that of limited natural resources, in addition to the spectrum of the problem of plant pathogens, which means is needed to produce more food with less resources, to ensure food security in environmental protection conditions (Paunescu et al., 2021). Plant bioengineering has led to significant improvements in crop yields, by including genes for resistance to herbicides, diseases, drought, etc. in plants genome (De Souza and Bonciu, 2022).

This paper outlines the results from the last three years, examining the effects of sowing time, plant density, and variety on the production and quality of winter wheat, in relation to the climatic conditions of each year.

MATERIALS AND METHODS

The field tests were carried out in 2022, 2023, and 2024, on a soil type specific to southern Romania (cambic chernozem). The soil's physical properties show a higher humus content in the top 15 cm, due to previous cultivation, which gradually decreases with depth.

The soil is composed of several horizons:

- Ap + Aph (0-30 cm): clay-loam with 36.5% clay, permeability of 492, pH 5.9.
- Am (30-45 cm): clay-clay, compacted with 37.3% clay, bulk density of 1.41 g/cm³, pH 5.9.
- A/B (45-62 cm), Bv1 (62-80 cm), Bv2 (82-112 cm), Cnk1 (149-170 cm), and Cnk2 (170-200 cm). Depending on the agricultural year, the soil's water supply is suitable for field crops, with groundwater levels at 10-12 meters.

The researchs was installed in a non-irrigated system on a land with uniform microrelief and with direct exposure to climatic conditions, especially severe drought. The experiment was trifactorial and placed in the field in randomized complete block design in three replications.

Factor A - sowing date with the following five graduations: SD I - September 20, SD II - October 01, SD III - October 10, SD IV – October 25 and SD V - November 10.

Factor B - plant density with the following two graduations: PD - 500 seeds/m^2 and PD - 600 seeds/m^2.

Factor C - varieties sown with the following two graduations: VS1- Ursita and VS2- Voinic, both developed at the NARDI Fundulea.

The main plots are 240 m^2 (30 m x 8 m) and the sub-plots 48 m^2 (6 m x 8 m). Wheat was cultivated after sunflower, as part of a four-year crop rotation.

To assess quality, samples were taken from each repetition and variant, and the following measurements were made:

- thousand grain weight - WTG was determined using the Kern precision electronic scale.
- hectoliter weight - HW was measured using a special cylinder, followed by weighing on the Kern scale.

Temperatures and precipitation for the 2022-2024 agricultural years were recorded at the NARDI Fundulea meteorological station

The data and analyses obtained were processed and statistically interpreted using the variance analysis method.

RESULTS AND DISCUSSIONS

Climatic aspects

The climatic conditions observed during the research period revealed notable differences between years, attributed to variations in temperature and precipitation distribution.

In 2021/2022, the months with the lowest rainfall were September, with 4.0 mm compared to the multi-year average of 48.5 mm; January, with 4.8 mm against the average of 34.1 mm; and August, with 14.4 mm, while the multi-year average was 49.7 mm. The highest precipitation was recorded in April, with 47.6 mm, which is 2.5 mm above the multi-year average. Between October 2021 and July 2022, the thermal regime showed that the monthly averages were above the multi-year average, with temperatures differing by 1.8°C from the multi-year average.

The agricultural year 2022/2023 was marked by dryness, with significant water shortages and higher temperatures compared to the multi-year average. The months with the lowest precipitation in 2022 were October, with 5.2 mm compared to the multi-year average of 42.3 mm; February, with 5.8 mm compared to the average of 32.0 mm; August, with 6.6 mm compared to the average of 49.7 mm; and March, with 10.0 mm compared to the average of 37.4 mm. In May, a significant amount of precipitation was recorded, totaling 77.2 mm, compared to the multi-year average of 45.1 mm, resulting in a difference of 32.1 mm.

The rainfall deficit affected the early stages of crop establishment and development, leading to reduced yields. The above-average temperatures worsened the drought conditions. The average temperature for the 2022/2023 agricultural year was 12.7°C, compared to the multi-year average of 10.8°C, showing an increase of 1.9°C.

The 2023/2024 year was notably dry, with a pronounced water deficit and elevated temperatures compared to the multi-year average. The months with the lowest rainfall were September, with 4.2 mm compared to the multi-year average of 49.5 mm; January, with 17.6 mm compared to 34.1 mm; and February, with 1.4 mm compared to the multi-year average of 32.0 mm.

November recorded the highest amount of precipitation, with 85.6 mm, which is 43.6 mm above the multi-year average. In terms of the thermal regime, from September to August, the average temperatures for the 2023-2024 agricultural year were 3.3°C higher than the multi-year average.

To determine the influence of climatic factors on the development of the wheat crop, the values obtained during various phenological phases were analyzed and compared with the final yield, considering both quantity and quality (Table 1). The annual climate data were also compared to the 50-year multi-year average, which recorded 584.3 mm of precipitation and a temperature of 10.8°C

Table 1. The meteorological parameters in the experimental period (NARDI Fundulea, 2022-2024)

Years/Months		Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Ma	Jun	July	Aug	Total/ Average
Precipitations (mm)	’21/’22	4.0	56.4	33.8	37.6	4.8	5.4	12.3	47.6	30.1	59.6	29.2	14.4	335.2
	’22/’23	35.4	5.2	19.6	21.8	64.2	5.8	10.0	77.2	32.4	40.2	43.8	6.6	362.2
	‘23/’24	4.2	29.0	85.6	24.4	17.6	1.4	38.6	62.4	34.2	15.6	45.4	18.0	376.4
50 years average		**48.5**	**42.3**	**42.0**	**43.7**	**35.1**	**32.0**	**37.4**	**45.1**	**62.5**	**74.9**	**71.1**	**49.7**	**584.3**
Temperatures (oC)	’21/’22	17.3	10.2	7.7	2.6	2.1	4.7	4.4	12.1	17.9	22.6	25.0	25.6	12.6
	’22/’23	18.6	13.5	9.0	3.5	4.9	3.3	8.2	10.8	16.9	22.3	26.1	26.1	12.7
	’23/’24	21.7	16.1	8.5	4.3	1.0	7.6	8.5	15.0	16.4	26.1	27.7	26.3	14.1
50 years average		**17.3**	**11.3**	**5.4**	**0.1**	**-2.4**	**-0.4**	**4.9**	**11.3**	**17.0**	**20.8**	**22.7**	**22.3**	**10.8**

Production and Quality

The influence of sowing date. The experimental results from 2022 showed a statistically significant effect of sowing date on wheat yield. When compared to the control variant (SD - September 20), the highest yields were achieved with sowing dates between October 10 and October 25.

The maximum yield of 4600 kg/ha was obtained on October 10, representing an increase of +39.4% relative to the control, a difference that proved to be statistically significant (**). Furthermore, the quality parameters of the grains, namely hectoliter weight and thousand kernel weight, exhibited a moderate upward trend during this period, reaching peak values of 79.0 kg/hl and 45.7 g, respectively. These findings underscore the importance of optimizing sowing time to enhance both yield and grain quality.

The influence of sowing density. Increasing the sowing density from 500 to 600 germinable seeds/m² resulted in a modest yield increase of approximately 7.3%, although this difference was not statistically significant. However, slight improvements were observed in grain quality indicators, with the hectoliter weight reaching 79.4 kg/hl and the thousand kernel weight 45.5 g. These results suggest that a slightly higher sowing density may offer a technological advantage, particularly under favorable environmental and agronomic conditions.

The influence of varieties sown revealed the comparison between the two tested wheat varieties - Ursita and Voinic - and demonstrated a clear superiority of the Voinic variety in terms of grain quality. The Voinic variety recorded a hectoliter weight of 79.0 kg/hl and a thousand kernel weight of 45.9 g, differences that were statistically significant (* and **). Although the yield of the Voinic variety exceeded that of Ursita by +4.8%, this increase was not statistically significant. Nonetheless, the combination of slightly higher yield and significantly improved grain quality indicates the Voinic variety's enhanced agronomic potential, particularly in intensive cultivation systems (Table 2).

Table 2. Production wheat crop values in 2022

Specification variant	Producţion /Diference			HW		WTG	
	(kg/ha)	(%)	Semnific.	kg/hl	%	g	%
A. Sowing date (SD)							
A1 - Mt	3300	100.0	0	77.3	100.0	44.2	100.0
A2	4150	125.7	850*	78.2	101.2**	45.3	102.5**
A3	4600	139.4	1300**	79.0	102.2***	45.6	103.2***
A4	4500	136.4	1200*	79.0	102.2***	45.7	103.4***
A5	3850	116.7	550*	78.0	100.9*	45.0	101.8**
DL (kg/ha / kg/hl / g)	DL= (P 5%= 525 /P 1% = 1015 / P 0.1% = 1909)			DL = (0.72 /1.19 /2.20)		DL= (1.01 / 1.53/3.20)	
B. Plant density (PD)							
B1 - Mt	4100	100.0	0	78.0	100.0	45.2	100.0
B3	4400	107.3	300	79.4	101.8*	45.5	100.7
DL (kg/ha)	DL= (P 5%= 520 /P 1% = 1005 /P 0,1% = 1880)			DL= (0.70/1.11 /2.23)		DL= (1.06/ 2.09 /3.18)	
C. Varieties sown (VS)							
C1 - Mt	4200	100.0	0	78.0	100.0	45.3	100.0
C2	4400	104.8	300	79.0	101.2**	45.9	101.3*
DL (kg/ha)	P 5%= (622 /P 1% = 1105 /P 0.1% = 1900)			DL= (0.68 / 1.12 / 2.01)		DL= (1.00 / 2.11 / 3.09)	

The experimental data from 2023 indicate a significant increase in yield with a delay in the sowing date. The highest yield of 5200 kg/ha was recorded with sowing on October 10th (A3), which represents a 36.8% increase compared to the control, with a statistically significant difference (**). This suggests that the optimal sowing period is around October 10th, as it enhances both the yield and quality of wheat in comparison to earlier or later sowing dates.

Regarding the grain quality parameters (HW and WTG), the observations reveal a slight increase in values as sowing is delayed, with peak values of 78.1 kg/hl for HW and 44.7 g for WTG at sowing on October 10th and 25th. Additionally, the increase in WTG values with later sowing suggests an enhancement in grain quality.

However, sowing at the beginning of November (A5) resulted in a decrease in yield (4550 kg/ha), while still maintaining a high level of grain quality. This indicates that although the optimal sowing date is closer to October, sowing too late may negatively affect yields, even if it does not drastically impact grain quality.

Increasing the sowing density from 500 seeds/m² to 600 seeds/m² led to an 8.9% increase in yield (from 4180 kg/ha to 4550 kg/ha). This difference is statistically significant (***), indicating that a higher plant density can significantly increase yield, suggesting that 600 seeds/m² is a favorable density for maximizing yield.

In terms of grain quality, hectoliter weight and thousand grain weight were slightly higher at the 600 seeds/m² density, suggesting that a higher plant density contributes to a modest improvement in wheat quality. For example, hectoliter weight increased to 78.7 kg/hl, and thousand grain weight reached 44.4 g. This suggests that higher plant density not only enhances yield but also contributes to a slight improvement in the quality of the grains.

The differences between the two tested varieties, Ursita and Voinic, are significant, with Voinic exhibiting higher yield and slightly better grain quality values. Voinic recorded a yield of 5300 kg/ha, representing a 10.4% increase compared to Ursita. Additionally, values for hectoliter weight and thousand grain weight are also slightly higher in Voinic compared to Ursita, suggesting that Voinic is more efficient in terms of both yield and quality (Table 3).

Table 3. Production wheat crop values in 2023

Specification variant	Production /Diference			HW		WTG	
	(kg/ha)	(%)	Semnific.	kg/hl	%	g	%
A. Sowing time							
A1 - Mt	3800	100.0	0	77.0	100.0	43.1	100.0
A2	4700	123.7	900*	78.0	101.3**	44.6	103.5***
A3	5200	136.8	1400**	78.1	101.4**	44.7	103.7***
A4	4700	123.7	900*	78.1	101.4**	44.7	103.5***
A5	4550	119.7	750*	78.0	101.3**	44.6	103.5***
DL (kg/ha / kg/hl / g)	DL= (P 5%= 620 /P 1% = 1120 / P 0.1% = 1955)			DL = (0.69 /1.10 /2.10)		DL= (1.03 / 1.67/3.10)	
B. Density							
B1 - Mt	4180	100.0	0	77.0	100.0	44.0	100.0
B2	4550	108.9	370	78.7	102.2***	44.4	100.9
DL (kg/ha)	DL= (P 5%= 604 /P 1% = 1001 /P 0.1% = 1985)			DL= (0.67 /1.12 /2.18)		DL= (1.01/ 2.01 /3.11)	
C. Variety							
C1 - Mt	4800	100.0	0	78.0	100.0	44.4	100.0
C2	5300	110.4	500	78.3	100.4	44.7	100.7
DL (kg/ha)	P 5%= (605 /P 1% = 1108 /P 0.1% = 1995)			DL= (0.68/ 1.05 / 2,05)		DL= (1.00 / 2.05 / 3.11)	

In 2024, sowing date influenced production, which varied significantly, with a trend of increasing yields as sowing was delayed. The highest yield was obtained for the sowing on October 10th (3990 kg/ha), followed by October 25th (3900 kg/ha), while the later sowing date (November 10th) resulted in a production of 3700 kg/ha, similar to the sowing on October 1st (3700 kg/ha).

Compared to the first variant (September 20th), the differences in production are statistically significant, falling within the 5% and 1% significance levels (*$p < 0.05$, **$p < 0.01$), suggesting that sowing at the optimal time provides production benefits despite potentially more challenging growing conditions.

The hectoliter weight is slightly higher for the sowing variants of October 1st and October 10th (76.1 and 76.8 kg/hl, respectively), compared to the other variants, which fluctuate around 75.2 kg/hl (September 20th). The thousand grain weight does not vary significantly between variants, but there is a slight increase as sowing is delayed. The sowing variants of October 10th and October 25th had a thousand grain weight of 43.2 g and 43.3 g, respectively, compared to 42 g for the sowing on September 20th.

Plant Density: the B1 variant (500 seeds/m²) recorded a yield of 2700 kg/ha, while for the higher plant density of 600 seeds/m² (B3), the yield increased to 3550 kg/ha. This difference is statistically significant ($p < 0.01$), meaning that the variation in production is largely due to plant density rather than other fluctuations.

Sown Varieties: compared to the Ursita variety, which recorded a yield of 3700 kg/ha, the Voinic variety produced a higher yield of 3950 kg/ha.

The increase in production for Voinic (6.7%) is significant ($p < 0.01$), indicating that the Voinic variety is more productive than Ursita under the tested conditions (Table 4).

Table 4. Production wheat crop values in 2024

Specification variant	Production/Diference			HW		WTG	
	(kg/ha)	(%)	Semnific.	kg/hl	%	g	%
A. Sowing time							
A1 - Mt	2900	100.0	0	75.2	100.0	42.0	100.0
A2	3700	119.4	800*	76.1	101.2**	43.1	102.6***
A3	3990	128.4	1090**	76.8	102.1***	43.2	102.9**
A4	3900	125.8	1000**	76.8	102.1***	43.3	103.1***
A5	3700	122.6	800*	76.8	102.1**	43.3	103.1***
DL (kg/ha / kg/hl / g)	DL= (P 5%= 500 /P 1% = 910 / P 0.1% = 1650)			DL = (0.55 /1.08 /2.10)		DL= (1.03 / 1.51/3.06)	
B. Density							
B1 - Mt	2700	100.0	0	75.0	100.0	43.0	100.0
B2	3550	131.5	850**	76.4	101.9**	43.4	100.9
DL (kg/ha)	DL= (P 5%= 452 /P 1% = 835 /P 0.1% = 1611)			DL= (0.60 /1.00 /2.04)		DL= (1.01/ 2.08 /3.01)	
C. Variety							
C1 - Mt	3700	100.0	0	75.7	100.0	43.1	100.0
C2	3950	106.7	250	76.0	100.4	43.5	100.9
DL (kg/ha)	P 5%= (495 /P 1% = 988 /P 0.1% = 1795)			DL= (0.68 / 1.10 / 2.20)		DL= (1.00 / 2.07 / 3.03)	

In 2023, the highest protein content was observed in the variant sown on October 25 at a density of 500 seeds/m² for the Ursita variety, with 13.9%. This was followed by the variant sown on October 1 at a density of 600 seeds/m² for the Voinic variety, with 13.5%. Of the functions available in the Windows program linear, logarithmic, polynomial, power, and exponential—the polynomial function exhibits the highest regression coefficient in modeling the relationship between agrotechnical factors (such as sowing date, seed density, and variety) and protein content in wheat (Figure 1).

Expanding the options for selecting the sowing date and determining the sowing density, particularly through the combination of these factors, leads to very positive correlations, with regression coefficients ranging from 0.01 to 0.93. Early sowing, when combined with a high sowing density, resulted in a lower protein content, with a regression coefficient of 0.37.

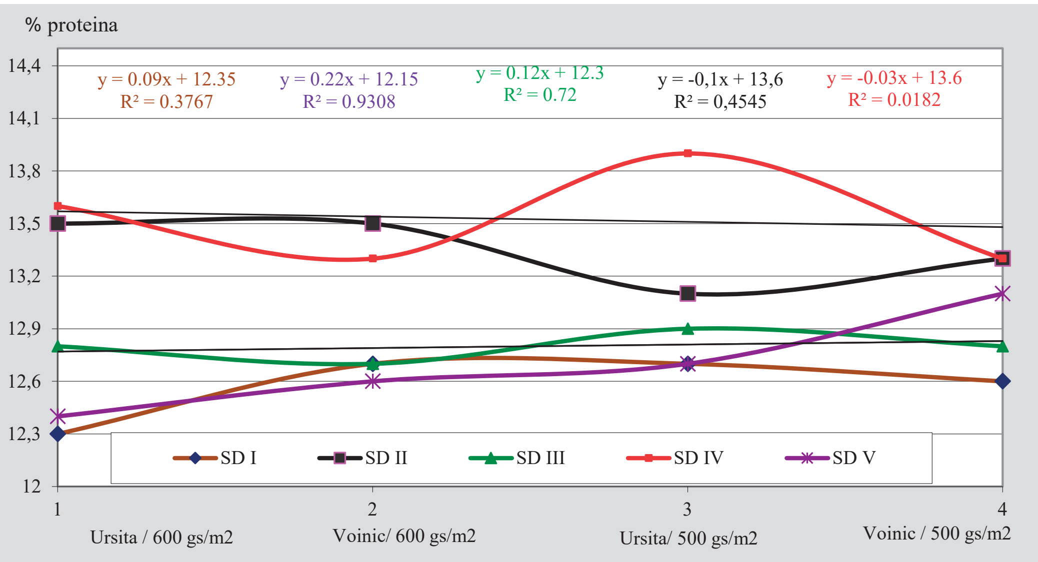

Figure 1. The correlation between wheat protein content and agronomic measures

CONCLUSIONS

The research findings indicate that sowing date, plant density, and variety significantly impact both the quantity and quality of wheat production, with the pedoclimatic conditions playing a key role. The applied agronomic practices have consistently contributed to the enhancement and stability of final yields and grain quality.

Regarding wheat cultivation technology, the following key observations were made: the optimal sowing window for maximizing both yield and quality is between October 10 and 25; slightly higher sowing densities offer some agronomic advantages, although yield increases are marginal; and the Voinic variety is recommended due to its superior grain quality, making it ideal for premium wheat production, with Ursita as a suitable alternative.

Protein content in wheat grouped the variants as follows: very good quality (>13%), good (12-13%), and satisfactory (8-12%). Sowing within the optimal period or later, along with plant densities of 600 seeds/m², led to an increase in protein content ranging from 12.1% to 13.9%, compared to the control variant.

In both 2022 and 2024, drought conditions impacted final yields regardless of the technological practices implemented. Temperature fluctuations and uneven precipitation distribution adversely affected wheat plants at all growth stages, reducing both yield and grain quality. Drought, depending on its intensity and duration, can severely damage the crop, and the variety's drought tolerance becomes a crucial factor in determining the plant's resilience.

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