RESEARCH ON THE PRODUCTION POTENTIAL OF WINTER WHEAT RESEARCH GROWN UNDER NON-IRRIGATED CONDITIONS ON DIFFERENT TYPES OF SOIL IN SOUTHERN OLTENIA

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Abstract

The purpose of this study was to study the behavior of wheat under non-irrigated conditions in the context of recent climate changes, with the objective of choosing the soil for the maximum manifestation of the plant's biological potential under conditions of thermohydric stress. In this sense, five work points were placed in plots sown with the Glosa wheat variety on two types of soil (loamy-sandy and chernozem), in order to evaluate the plant's behavior according to fertility. The obtained results highlighted a degree of twinning of the plant of about 89.74%, in the wheat crop placed on chernozem, exceeding by 16.8% the degree of twinning recorded in wheat plants grown on sandy-loamy soil, where the average of the analyzed points was 72.94%. The analysis of the phytosanitary state of the wheat crop revealed a degree of attack of 46-64% caused by the infection with Puccinia striiformis + Septoria tritici and 0-1.9% caused by Erysiphe graminis, the intensity of the attack being slightly higher with the sown wheat on the chernozem type soil as a result of a higher density of plants and the induction of a wetter microclimate the architecture of the leaf apparatus. The results obtained during the harvesting of the plant, highlighted the recording of the highest productions in the plots of wheat sown on chernozem soil (3664-4735kg/ha), exceeding on average by 82.5% the production recorded on sandy-loamy soil.

Key words: soil fertility, wheat, plant biology, productivity, grain quality

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the crops of great importance for world agriculture, being the most cultivated and consumed cereal. Also called the “king of cereals” or the “plant of plants”, wheat is the oldest plant cultivated by man over 10,000 years ago in the Middle East (Charmet, 2011), and in our country it has been cultivated since the Neolithic (Nedelciuc et al., 2002). Climate change in the last decade represents the main problem of this century. The greenhouse effect and the thinning of the ozone layer determine the accelerated warming of the climate throughout the globe. This warming results in the production of meteorological phenomena such as: drought, floods, torrential rains, etc. (Gumovschiht, 2011). The increase in global average temperature, associated with a higher frequency of extremely hot days, can affect the metabolism of wheat plants. Thus, research conducted in Australia has shown that variations in average temperatures of +/-2°C, recorded during the wheat growing season, can cause reductions in production of up to 50% (Asseng et al., 2011). Also, future climate scenarios suggest that global warming could be beneficial for wheat crops in certain regions, but could reduce production in areas where optimal temperatures already exist (Ortiz et al., 2008). Drought causes essential physiological changes including: slowing or even stopping plant growth; decreasing the water retention capacity at the cellular level; decreasing the intensity of the photosynthesis process and increasing non-productive respiratory processes (Qing Mu et al., 2022). In wheat, long-term drought causes the phenomenon of grain shrinkage, a reduction in the number of spikelets, flower abortion and stagnation of the growth of the main stem and siblings, and heat - characterized by maximum temperatures above 42°C, causes the disruption or even blocking of the growth, development and metabolism processes of wheat plants (Shivalal et al., 2023). Although in winter wheat the leaves maintain a temperature 1-2°C lower than the ambient temperature, heat causes wilting, and the grains may present necrotic spots when the soil temperature exceeds 50°C (Milică et al. (1974). In Romania, Croitoru et al., 2012, studied the climate changes in the country during the period 1956 - 2009 and their impact on the vegetation period of the wheat crop, highlighting the precocity of the anthesis period in wheat by approximately 1-3 days/decade and the reduction of the grain filling period by approximately 1 day/decade. The decrease in soil fertility and the decrease in soil quality have threatened the ecological and economic sustainability of agricultural wheat production. In this regard, the experiments undertaken on weathered reddish-brown Nitisol areas of Welmera and Addisalem Districts of West Shewa, central highlands of Ethiopia showed that soil fertility determined the increase of 141% and 149% in grain yield and total biomass in wheat (Agegnehu et al., 2014). Although the variety is an important factor in technology that does not require any other investment, however, by cultivating it in unsuitable areas and on poorly fertile soils it cannot value its biological potential for which it was created, the results obtained being unprofitable ((Mustățea et al., 2003). Therefore, the choice of land and the monitoring of the growth and development processes of the wheat plant under the conditions of increasing drought in the southern area of Oltenia are objectives that will be investigated in this study.

MATERIALS AND METHODS

This study presents the results of research from the 2022-2023 agricultural year on the behavior of the *Glosa* wheat variety, cultivated under non-irrigation conditions, on different soil types within the Development Sector of Research Development Station for Plant Culture on Sands Dăbuleni (RDSPCS Dabuleni). The research was carried out on wheat sown on two types of soil: sandy loam and chernozem, on which five variants were placed, as follows: G1, G2, G3, on sandy loam soil and G4, G5, on chernozem soil. The experimental plot area was 1000 m². The studies were carried out under non-irrigated conditions with the application of the wheat cultivation technology developed by RDSPCS Dăbuleni (Drăghici et al., 2014) and the updating of some phytosanitary products applied in vegetation (*Falcon Pro* fungicide, at a dose of 0.8 l/ha + *Faster 10 CE* insecticide, at a dose of 0.15 l/ha; herbicide).

During the wheat vegetation period, observations were made on the soil fertility status, plant phenology, twinning degree, phytosanitary status of plants, as well as the establishment of productivity elements and the estimation of production and quality, according to the standard methodology (Drăghici, 2022; Croitoru, 2021).

For the analysis of soil fertility, in terms of nutrient content, standard methods were used (extractable phosphorus (P-AL), by the Egner – Riem Domingo method; exchangeable potassium (K-AL), by the Egner method, organic carbon, by the wet oxidation method and titrimetric dosing (according to Walkley – Blak in the Gogoaşa modification) and soil pH - potentiometric method. The humus content was determined by the formula: C_{org} x 1.724.

RESULTS AND DISCUSSIONS

The results of the chemical analyses performed on the basic agrochemical properties of the variants studied are presented in Table 1. The analysis of the soil quality where the work points were established highlighted a great unevenness of the land in the Development sector of RDSPCS Dabuleni, according to the supply domain developed by Davidescu et al. (1981). Thus, the chemical quality analyses of the loamy-sandy soil identified in plots G1, G2, G3 revealed, on average on the 0-75 cm soil profile, a reduced supply in total nitrogen (0.06-0.08%), normal in extractable phosphorus (37.17-43.88 ppm), reduced to medium in exchangeable potassium (57.6-70.4 ppm), medium in organic carbon (0.73-1.1%) and a moderately acidic reaction, with a soil pH of 6.2-6.25. A better natural fertility was noted in the chernozem soil identified in plots G4 and G5. The chemical analyses carried out on the chernozem soil revealed a reduced to medium supply in total nitrogen (0.06-0.11%, a normal supply in extractable phosphorus (50.23-60.99 ppm), medium in exchangeable potassium (66.13-121.6 ppm) and normal fertility in terms of organic carbon content (1.84-2.05%) and implicitly in humus (3.18-3.53%). The reaction of the chernozem soil type showed a moderately acidic pH, the values being closer to normal, compared to the sandy loam soil.

Table 1. Analysis of the average soil fertility status on the 0-75 cm profile under the winter wheat crop within the RDSPCS Dabuleni

Lot name/soil type		Nt (%)	Extractable phosphorus (ppm)	Exchangeable potassiu (ppm)	Organic carbon (%)	Humus (%)	pH
G1: sandy loam		0.07	43.88	70.4	0.73	1.25	6,25
G2: sandy loam		0.08	37.17	66.13	1.1	1.9	6,2
G3: sandy loam		0.06	40.86	57.6	0.97	1.68	6,23
G4: chernozem		0.06	60.99	66.13	1.84	3.1â	6,38
G5: chernozem		0.11	50.23	121.6	2.05	3.53	6,71
Supply area (Davidescu D. et al., 1981)	low	< 0.10	18.1 - 36	66.1 - 132	0.59 – 1.16		5,01-5,80 Weakly acidic* 5,81-6,8 Moderately acidic* 6,81-7,20 Neutral
	medium	0.11 - 0.15	36.1 - 72	132.1 - 200	1.17 – 2.32		
	normal	0.16 - 0.20	72.1 - 144	200.1 - 400	2.33 – 4.64		
	very good	0.21 – 0.30	>144	>400	-		

The 2022-2023 agricultural year was a year characterized by special climatic conditions both in winter and in summer. In terms of the thermal regime, in the period 1.09.2022 - 28.02.2023 it recorded values relatively close to the multiannual average and above the multiannual average, with values ranging between 3.5-17.9 ºC, without inducing negative influences on plant vegetation, avoiding a decrease in the number of plants during the winter period (Table 2). Both in the autumn and in winter, the climatic conditions did not negatively influence plant vegetation, so that at the end of winter the crop was completed, having a normal density. The temperatures recorded in the period September - November allowed the optimal completion of the phenophases until the beginning of winter, ensuring very good vegetative growth. The year 2023 began with abundant precipitation in the form of rain, but also snow (101.8 mm), which provided a protective layer for wheat. Although low temperatures were recorded during the winter, the snow cover protected the wheat crop, the negative temperatures being little felt by the plants. Following the distribution of precipitation during the vegetation period, it is observed that during the vegetative rest period of the wheat crop, the precipitation fell was quantitatively significant (289.80 mm), exceeding the multiannual average values by 37.74 mm. During the intensive growth-flowering period, when the requirements of wheat plants are increased in terms of water, the recorded precipitation was higher than the multiannual average values. The relative air humidity in this area showed values that ranged between 68% in September 2022 and 86.3% in January 2023, with continuously decreasing values in March, April and May, a period in which the air temperature constantly increased

Table 2. Climatic conditions recorded during the wheat growing season 2022-2023

Climate element	IX	X	XI	XII	I	II	III	IV	V	VI	Amount (^{0}C) Average (mm)
Average temperature (^{0}C)	17.9	13.3	8.8	2.76	4.03	3.5	8	11.1	16.8	21.2	10.93
Absolute maximum (^{0}C)	34.1	25.9	26.7	14.5	22	23.1	21.6	23.5	29	37.6	25.8
Absolute minimum (^{0}C)	3.9	- 0.4	- 2	- 4.3	- 4.3	- 11.8	- 5.9	0	7.4	11.4	- 0.6
Precipitation (mm)	56.4	18.6	53.8	42	101.8	17.2	36	57.8	81.6	81.4	546.6
Humidity (%)	68	68.7	81.71	89.66	86.3	71.7	67.2	67.1	66.9	70.6	73.7
Multiannual average temperature (1956-2022) ^{0}C	17.93	11.50	5.69	0.65	- 1.33	1.19	5.87	11.86	16.94	21.54	9.18
Multiannual average temperature (1956-2022)	44.92	43.52	43.12	49.88	36.25	32.41	40.67	47.12	62.67	70	470.56
Deviation from the multiannual average temperature (^{0}C)	-0.03	1.8	3.11	2.11	5.36	2.31	2.13	-0.76	-0.14	-0.34	1.555
Deviation from the multiannual water regime(mm)	11.48	-24.92	10.68	-7.88	65.55	-15.21	-4.67	10.68	18.93	11.4	76.04

Plant density determinations at the end of winter showed values ranging from 432-656 plants/m², depending on soil type and plot location (Table 3). Regarding the development of wheat plants, soil temperature and humidity determined good twinning of wheat plants, with the highest degree of twinning (80.49-100%) recorded in the crop sown on chernozem soil (G4 and G5). In terms of the number of siblings formed per plant, wheat sown on sandy loam soil recorded a higher percentage of plants with 3, 4 and 5 siblings per plant (22.5%; 13%; 2.3%), compared to wheat sown on chernozem soil which recorded a higher percentage of plants that formed 1-2 siblings/plant, respectively 41.4% and 23.97%. The average results regarding the number of twinned plants highlighted a higher twinning degree on chernozem of approximately 89.74%, exceeding by 16.8% the twinning degree recorded in wheat plants grown on sandy-loamy soil, where the average of the analyzed points was 72.94%. The growing season of winter wheat lasts in our country's conditions about 270-290 days. During this period, from germination to maturity, wheat plants go through certain phenological phases (stages) that are recognizable by changes in the external appearance of the plants and which are accompanied by internal changes in the biology of the plant. As a rule, it is difficult to strictly delimit these phases, because they partially overlap or occur in parallel.

In general, it is accepted to divide the growing season of wheat plants into the following phenological phases: germination, rooting, twinning, straw formation (elongation), earing-flowering-fertilization, grain formation and maturation. In turn, the presented phases are grouped into: the vegetative stage (period), characterized by the development of the vegetative organs of the plants (from germination to flowering) and the generative (reproductive) stage characterized by the development of the inflorescence, flowers and the formation of grains - from the beginning of the elongation of the straw to full ripening (Roman Gh., 2011).

In order to more accurately assess the vegetation phases, they have been coded. Through coding, the vegetation period is divided into phenological stages that are numbered in a numerical system, forming the so-called code scales, the most widely used currently being the BBCH scale. Knowing the growth stages is useful for deciding the right time for various technological interventions. At the same time, observing them is useful for identifying critical stages in the vegetative cycle of plants, in which they are more sensitive to environmental factors.

Within the RDSPCS Dăbuleni, the wheat crop was monitored starting from February 15, 2023, throughout the vegetation period and phenological observations were made (Table 4).

Thus, the BBCH stages were the following: twinning - BBCH 21-29 (carried out until around 13.03.2023), straw elongation - BBCH 32 - 49 (which represents the end of the vegetative phase), phenophase that ended on April 25, 2023, earing - BBCH 51 (08.05.2023), flowering - BBCH 59 - 69 (22.05-28.05) grain formation and milk maturity - BBCH 71 (9.06), full maturity - BBCH 89 (26.06.2023). In the conditions of the year 2023, the winter wheat carried out all its stages of plant development in a time of 256 days, by accumulating in the air a total thermal resource of 2419 ºC, the highest thermal resource (843 ºC) being necessary in the period between the emergence of the plant until the registration of 4-5 siblings on the main stem (BBCH 29), this period lasted 149 days.

Table 3. Determination of the degree of twinning in winter wheat at RDSPCS Dăbuleni on 1.03.2023

Lot name/soil type	No. plants / m^2 with 1 sibling		No. plants / m2 with 2 siblings		No. plants / m2 with 3 siblings		No. plants / m2 with 4 siblings		No. plants / m2 with 5 siblings		Non-twinned plants/m^2		No. total plants / m^2	Plants with formed siblings (%)
	No. pl.	%	No. pl	%	No. pl	%	No. pl	%	No. pl	%	No. pl	%		
G1: loam sandy	112	23.33	80	16.67	128	26.67	64	13.33	16	3.33	80	16.67	480	83.33
G2: loam sandy	96	21.43	48	10.71	80	17.86	32	7.14	16	3.57	176	39.29	448	60.71
G3: loam sandy	64	14.81	80	18.52	96	22.22	80	18.52	0	0	112	25.93	432	74.07
Average clay-sandy soil	90.67	19.86	69.33	15.30	101.33	22.25	58.67	13.00	10.67	2.30	122.67	27.30	453.33	72.94
G4: chernozem	288	48.65	96	16.22	160	27.03	48	8.1	0	0	0	0	592	100
G5: chernozem	224	34.15	208	31.71	96	14.63	-0	0	0	0	128	19.51	656	80.49
Average soil chernozem	256	41.4	152	23.97	128	20.83	24	4.05	0	0	64	9.76	624	89.74

Table 4. Vegetation phases and stages of wheat grown under non-irrigated conditions on different soil types

Vegetation phase	Vegetation stages	BBCH scale	Observation date	Observations regarding the recording of vegetation stages	
				No. of days	Total thermal resources (ºC)
Twining	Main stem with 2-3 siblings	21-25	15.02.2023	123	639
	Main stem with 4-5 siblings	29	13.03.2023	26	204
Straw elongation	2 or more nodes visible	32-36	18.03.2023	5	33
	Banner leaf visible	39	10.04.2023	23	128
	First awns visible	49	25.04.2023	15	197
Heading	Start of spikelet	51	08.05.2023	15	196
Flowering	Full inflorescence development	59	22.05.2023	14	233
	Full flowering	69	28.05.2023	6	137
Grain formation and milk maturity	Watery grain, first grains formed are half their final size	71	9.06.2023	12	256
Full maturity	Full maturity	89	26.06.2023	17	396

* Plant emergence date: 15.10.2022

The climatic conditions recorded in the last decade of April, with average temperatures of 10-13.9 ºC and a relative air humidity with an average of 63.22% and maximums between 72-100%, favored infection with pathogens and the sporadic appearance of pests in the wheat crop in the BBCH 39-41 phase. In the conditions of 2023, massive infections with yellow rust (*Puccinia striiformis*) were reported in the wheat crop, starting from the basal leaves towards the upper part of the plant, even reaching the flag leaf. Yellow rust is favored by cold and wet springs, the optimal temperature for the incubation of the disease being between 10 ºC and 15 ºC, and high atmospheric water saturation, conditions that were recorded during this period in our area and which favored a significant infection of the wheat plant. Also, infection with brown leaf spot (*Septoria tritici*) was reported with a lower intensity, especially on the leaves at the base, contamination being through the spores of the fungi present on the infected plant debris, in which the pathogens persist in the form of mycelium and pycnidia. The specialized literature shows that pycnospores germinate in wide temperature ranges from 2-8 ºC, the optimum being 20 – 26 ºC. The results obtained showed that in wheat sown on chernozem soil, due to the higher plant density and better water conservation in the soil creating a humid microclimate at the foliar level, the attack produced by the wheat powdery mildew infection (*Erysiphe graminis*) was present. The infection manifested itself on the basal leaves, after which it spread to the sheaths and the stem. Among the pests, the wheat bug (*Eurigaster integriceps*), the wheat thrips (*Haplothrips tritici*), the wheat wasp (*Cephus pygmaeus*) were sporadically reported. The analysis of the phytosanitary status of the wheat crop grown in a sandy-loam soil revealed a 46-62% attack rate caused by infection with *Puccinia striiformis* + *Septoria tritici*. In these plots (G1, G2, G3) the presence of the pathogen *Erysiphe graminis* was not reported. The determinations regarding the attack rate caused by foliar diseases in wheat grown on chernozem soil revealed a 62-64% attack rate caused by infections with *Puccinia striiformis* + *Septoria tritici* and a 0-1.9% attack rate caused by infection with the pathogen *Erysiphe graminis* (Table 5). Analyzing the influence of the soil on infections caused by pathogens, a greater sensitivity of wheat grown on chernozem soil is noted, as a result of a higher density and the induction of a wetter microclimate in the architecture of the leaf apparatus.

Table 5. Analysis of the phytosanitary status of wheat crop depending on soil type

Soil type/Working point	*Puccinia striiformis + Septoria tritici*			*Erysiphe graminis*		
	Attack frequency (%)	Attack intensity (%)	Attack degree (%)	Attack frequency (%)	Attack intensity (%)	Attack degree (%)
Sandy loam (G1)	100	54	54	0	0	0
Sandy loam (G2)	100	62	62	0	0	0
Sandy loam (G3)	100	46	46	0	0	0
Limits of variation loamy-sandy soil	100	46-62	46-62	0	0	0
Chernozium (G4)	100	62	62	8.33	23	1.9
Chernozium (G4)	100	64	64	0	0	0
Limits of chernozem soil variation	100	62-64	62-64	0-8.33	0-23	0-1.9

Production capacity is a complex quantitative character, determined by intrinsic factors (production components) and influencing factors (resistance to the action of external factors). Thus, specialized literature mentions that wheat production, after all, depends on the general genetic potential of the plant, the number of grains/surface unit and the weight of the grain, the latter being the resultant between the grain filling rate and the period of time in which it was achieved (Gebeyehou et al., 1982; Kamaluddin et al., 2007).

The determinations regarding the productivity elements (Table 6) showed that the number of harvestable ears per unit area, which is a very important production component of winter wheat, ranged between 405-481 ears/m^2, with an average of 432.3 ears/m^2, for wheat grown on sandy-loam soil and between 370-547 ears/m^2 with an average of 458.5 ears/m^2, for wheat grown on chernozem soil. Analyzing the ear length, a higher average value was noted for plants sown on chernozem soil (7.49 cm), these also recording a higher number of grains per ear of 27.5 grains/ear, exceeding by 3.2 grains/ear the average recorded for plants grown on sandy-loam soil.

The production results obtained at harvest showed yields ranging from 1793-2736 kg/ha, with an average of 2767.3 kg/ha for the variants located on sandy loam soil and 3664-4735 kg/ha, with an average of 4199.5 kg/ha for the variants sown on chernozem. By cultivating wheat on a more fertile soil, of the chernozem type, an average increase of 82.5% was recorded, compared to the production obtained on sandy loam soil. Also, table 6 highlights positive correlations of the production obtained on different soil types with the number of ears, the length of the ear and the number of grains per ear.

Table 6. Productivity elements of wheat cultivated under non-irrigated conditions on different soil types

Soil type/Working point	No. of ears/m^2	No. of grains in ear	Ear length (cm)	Average production kg/ha
Sandy loam (G1)	405	25	7.72	2272
Sandy loam (G2)	411	22	6.60	1793
Sandy loam (G3)	481	26	6.64	2737
Average sandy loam soil	432.3	24.3	7.0	2267.3
Chernozem (G4)	370	28	7.76	3664
Chernozem (G5)	547	27	7.22	4735
Average chernozem soil typ	458.5	27.5	7.49	4199.5

The analysis of the physical and chemical quality of grain production in wheat cultivated in the 2022/2023 agricultural year revealed differences depending on the soil type and experimental plot (Table 7).

Table 7. Physical and chemical quality indices of wheat grain obtained in different locations, depending on soil type

Soil type/Working point	WTG (g)	WH (kg/hl)	Total protein (%)	Gluten (%)
Sandy loam (G1)	39.71	71.6	13.3	30.2
Sandy loam (G2)	39.28	70.8	12.7	29.7
Sandy loam (G3)	45.55	73	13.7	31.3
Average sandy loam soil	*41.51*	*71.80*	*13.23*	*30.40*
Chernozem (G4)	43.16	71.4	12.5	28
Chernozem (G5)	44.75	71.4	13.7	31.9
Average chernozem soil	*43.96*	*71.40*	*13.10*	*29.95*

Thus, the weight of a thousand grains (WTG), which is a trait determined genetically, but also by environmental factors (soil fertility, climate), presented the maximum value of 43.96 g in wheat cultivated on chernozem soil, exceeding by 2.44 g the WTG, recorded in the production obtained on sandy-loam soil. The hectoliter weight (WH) ranged between 71.4 - 71.8 kg/hl depending on soil fertility. From the point of view of chemical quality, the protein content was higher by 0.13% in wheat grain obtained on sandy-loam soil, with a negative correlation with the level of production. Gluten plays a key role in determining the baking quality, conferring water absorption capacity, viscosity and elasticity to the dough (Wieser, 2007). In general, the higher the protein content, the longer the gluten formation time (Marinciu & Șerban, 2018). The highest gluten content values were recorded at points G3 (31.3%) and G5 (31.9), positively correlating with protein content of 13.7% (G3) and 13.7% (G5).

CONCLUSIONS

Under the conditions of 2023, winter wheat went through all the stages of plant development, noted according to the BBCH scale in a time of 256 days, by accumulating in the air a total thermal resource of 2419 ^{o}C.

The productivity and quality of winter wheat production were strongly influenced by the limiting abiotic conditions (thermal and water stress) manifested during the experimentation period, as well as by the type of soil.

The average results regarding the number of twinned plants highlighted a higher twinning degree on chernozem of approximately 89.74%, exceeding by 16.8% the twinning degree recorded in wheat plants cultivated on sandy-loamy soil, where the average of the analyzed points was 72.94%.

The analysis of the phytosanitary status of the wheat crop revealed a degree of attack of 46-64% caused by infection with *Puccinia striiformis* + *Septoria tritici* and 0-1.9% caused by Erysiphe graminis, the intensity of the attack being slightly higher in wheat sown on chernozem soil as a result of a higher plant density and the induction of a wetter microclimate and leaf structure. The results obtained at harvest highlighted the highest production recorded in wheat plots sown on chernozem soil (3664-4735 kg/ha), exceeding on average by 82.5% the production recorded on sandy loam soil.

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