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VARIABILITY OF WINTER WHEAT AGRICULTURAL YIELDS UNDER THE INFLUENCE OF THERMAL RESOURCES. CASE STUDY: CONTINENTAL DOBROGEA, ROMANIA

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Abstract

The study aims to focus on the analysis of winter wheat yields obtained in the context of the thermal resources available in the continental Dobrogea Region. The thermal resources play a crucial role in determining the length of the growing season, the sowing time, as well as the physiological processes of the plant and last but not least, in the production obtained at the end of the growing season. In achieving this study, there have been used the average production data per hectare from the National Institute of Statistics and the monthly meteo-climatic data on air temperature and spring index from six representative meteorological stations belonging to the National Meteorological Administration, for the period 1991 – 2023. The results of the study has highlighted the importance of the thermal factor in the development of the phenological stages of winter wheat in the study area, with agricultural yields varying between 296 kg/ha (2003) and 5,133kg/ha (2018), for the analyzed period. Knowing the requirements of the winter wheat crop in relation to the thermal resources offers farmers the possibility to maximize its production.

Key words**:** *agricultural yields, thermal resources, winter wheat, variability, Dobrogea Region*

INTRODUCTION

Winter wheat is one of the most important cultivated plants, for about 40% of the global population [9]. Grown in Romania, it is used for both domestic and foreign consumption throughout Europe. The yield and productivity of winter wheat crop are particularly influenced by climatic factors (light, air temperature, soil temperature, precipitation etc.) [7; 15]. Like other crops, winter wheat has certain bio-climatic requirements which have a significant influence on the growth and development processes of the plants and their productivity [14].

The aim of this analysis is to highlight the variability of winter wheat crop yields in relation to the influence of thermal resources. Air temperature plays a particularly important role in the growth and development of the winter wheat. The phenological phases of winter wheat are optimally produced when a certain amount of effective temperatures are accumulated, which influence the plants ability to develop and not least impact on the final crop yield. Production, like the areas cultivated with cereals, greatly depends on the agroclimatic resources, which play an extremely important role in the quality of the crops.The analysis of the thermal regime in an area highlights the ability to factually estimate the thermal resources needed for a crop, especially in the current context of climate change. The study region for which the analysis of the variability of winter wheat crop yields in relation to the influence of thermal resources is carried out is the Continental Dobrogea (Fig 1). Located in the South-Eastern Romania, the Continental Dobrogea is a region recognized for its economic importance in the field of agriculture, a large part of which is made up of arable land.The

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relief is represented by varied, slightly undulating plateaus, with average altitudes of 100 – 300m [12]. Climatically, the study area is characterized by a temperate continental transitional climate with arid climatic influences.

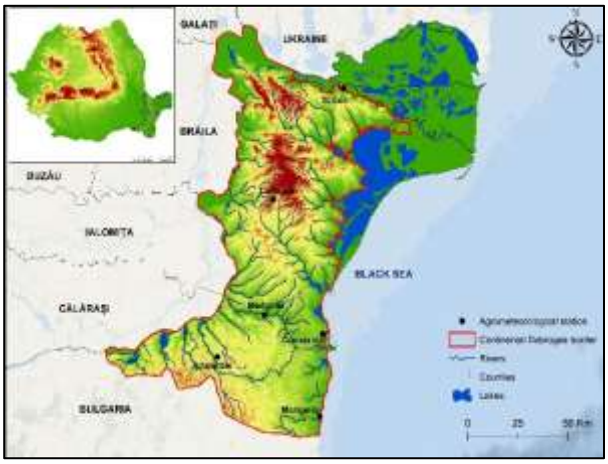

Fig. 1. The location of the study area and of the analyzed agrometeorological stations.
Source: own processing from GIS open sources.

MATERIALS AND METHODS

For the study of the variability of autumn wheat yield in relation to the influence of thermal resources, data on average production per hectare from the National Institute of Statistics (NIS) for the period 1991–2023 were analyzed and processed.These data reflect the variability of productions in relation to the analyzed thermal resources. In order to highlight the influence of thermal resources on winter wheat production, meteorological and agrometeorological data were used from six meteorological stations with agrometeorological programs within the network of the National Meteorological Administration (NMA), for the period 1991–2023. The analyzed agrometeorological stations are considered representative for the area of the Continental Dobrogea and have altitudes ranging between 4 m (Tulcea) and 219 m (Corugea) (Fig 1). From a meteorological perspective, data on the annual regime of the monthly average temperature (°C), the averages of the maximum and minimum monthly temperatures (°C) were used.

The agrometeorological indicator analyzed, which complements the study of thermalresources is the spring index.This index is expressed in 'heat units' and represents the sum of the average air temperatures greater than 0°C ($\sum T_{med.}$ >0°C).The spring index is a specific agrometeorological parameter that characterizes the thermal potential of the transition period from winter to spring for agricultural plants in the growing season [3]. These data have been processed, centralized and represented in graphical and tabular form, in Microsoft Excel and with the help of GIS techniques.

RESULTS AND DISCUSSIONS

Agricultural yields are influenced by thermal indicators, which play a significant role in the growth and development phases of winter wheat crops [5]. The rhythms of biological processes in agricultural crops vary depending on their thermal resource requirements, with the intensity of physiological processes, being directly related to the thermal fluctuations within specific limits for each genotype [10].

Depending on the plant species, whether thermophilic or mesophilic and the biological phases (germination, first leaf through coleoptile, 3 leaves unfolded etc.), the temperature requirements of agricultural crops vary.

Agricultural plants need to reach specific thermal thresholds (temperature sums) to successfully progress through each phenological phase. For example, during the October-December period, winter wheat undergoes the vernalization process, which is essential for its transition to the generative stage. This stage includes beginning of stem elongation, beginning of heading, flowering, fertilization, grain formation and ripening [5]. This process takes place from the beginning of autumn until the end of December. Depending on the sowing date, winter wheat requires a minimum accumulated temperature sum of 500°C during this period. This threshold is considered optimal for the requirements of winter wheat crops [4; 5].

Agricultural production

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The productivity of winter wheat is predominantly influenced by changes in the thermal regime, leading to significant annual yield fluctuations. Table 1 presents the annual average production per hectare recorded in the Continental Dobrogea during the period 1991–2023.

Table 1. The average production per hectare (kg/ha) of the winter wheat in the study area (1991–2023)

Year	Average of production (kg/ha)
1991	2,676
1992	1,693
1993	2,129
1994	1,152
1995	2,564
1996	1,991
1997	2,948
1998	2,229
1999	2,622
2000	1,917
2001	1,831
2002	1,977
2003	**296**
2004	3,145
2005	3,024
2006	3,069
2007	1,154
2008	3,477
2009	1,770
2010	2,519
2011	3,860
2012	2,133
2013	2,946
2014	3,468
2015	3,752
2016	4,037
2017	5,060
2018	**5,133**
2019	4,230
2020	1,282
2021	4,912
2022	4,101
2023	3,521
1991-2023	**2,806**

Source: processed data from NIS, 2025 [13].
Note: light yellow – the lowest average production per hectare; dark yellow – the highest average production per hectare.

Environmental factors, especially the climatic ones, cause the yields of winter wheat crops in the analyzed region to vary from year to year. Winter wheat yields have varied between 296 kg/ha in 2003 and 5,133 kg/ha in 2018. The average production recorded during the period 1991-2023 is 2,806kg/ha.The average yields recorded in 2003 began to decline, mainly due to the meteorological phenomena (extreme temperatures, low precipitation), which impact the crop while it is in the vegetation stage.The year 2003 was considered one of the driest years recorded in the decade 2001-2010, from a meteorological perspective. The year 2018 was a normal year in terms of both precipitation and temperature. The agrometeorological conditions of the 2017-2018 agricultural year were generally favorable in terms of temperature and precipitation for winter wheat cultivation compared to previous years, which led to high yields in the analyzed region [2].

Air Temperature Regime

Air temperature is an important meteorological factor in agriculture, as it triggers certain processes in plants, such as the advancement or delay of phenological phases in agricultural crops [8]. At the same time, this parameter is essential for ensuring the yield of winter wheat crops at the end of the vegetative season.

From the analysis of the six meteorological stations with agrometeorological programs, the multiannual average temperature (Fig. 2) ranges between 11.1°C at Corugea and 12.6°C at Constanța. The achievement of this multiannual average temperature is largely influenced by the fact that at most meteorological stations analyzed with agrometeorological programs, negative monthly average air temperatures were recorded only in January. The average monthly temperature in February increases significantly, by more than 1°C compared to January, due to the intensification of global radiation as well as the strengthening of cyclogenesis processes in the Mediterranean Sea [6].

Atmospheric circulation determines the movement of air masses with different thermal characteristics, leading to a distinct evolution of temperature values depending on the season. Air temperature fluctuates monthly across most of the area, as confirmed by the values of the monthly maximum temperature averages, ranging between 27.0°C (Constanța) and 29.8°C (Tulcea) in July (Table 2).

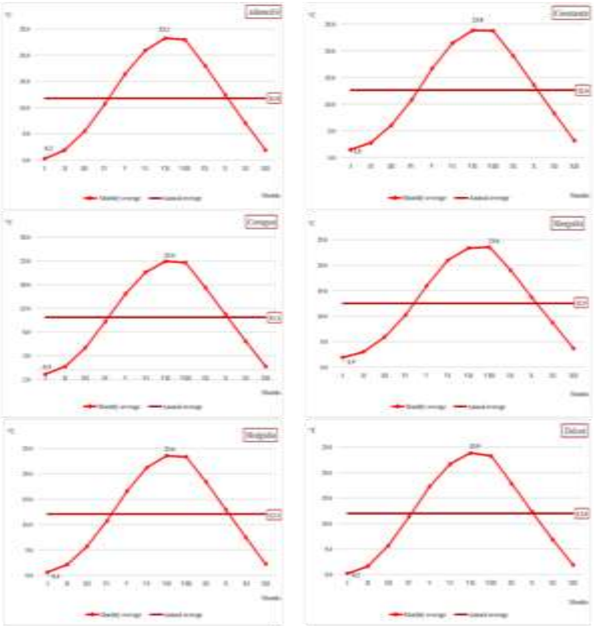

Fig. 2. The annual regime of air temperature (°C) at the agrometeorological stations analyzed for the period 1991–2023: Adamclisi (top left), Constanța (top right), Corugea (middle left), Mangalia (middle right), Medgidia (bottom left) and Tulcea (bottom right).
Source: processed data according to NMA, 2025 [1].

Table 2. Average monthly maximum and minimum temperatures (°C) at the agrometeorological stations analyzed for the period 1991–2023

Agrometeorological station	Average monthly minimum temperature (°C)												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual average
Adamclisi	-2.7	-1.5	1.6	6.1	11.2	15.5	17.5	17.4	13.0	8.4	3.7	-1.0	7.4
Corugea	-3.9	-2.5	0.7	5.3	10.5	14.9	16.9	17.6	12.3	7.5	3	-2	6.6
Constanța	-1.3	-0.2	2.8	7.3	12.6	17.0	20.1	19.3	15.0	10.3	5.4	0.4	9.0
Mangalia	-0.9	0.1	3.8	7.2	12.5	16.9	20.0	19.3	15.1	10.6	5.9	0.9	9.1
Medgidia	-2.3	-1.2	1.9	6.3	11.5	15.8	17.9	17.9	13.5	8.9	4.2	-0.7	7.8
Tulcea	-2.6	-1.8	1.7	6.5	11.8	16.1	18.0	17.2	12.5	7.8	3.3	-1.3	7.4
Continental Dobrogea average	**-2.5**	**-1.2**	**2.0**	**6.5**	**11.7**	**16.6**	**18.1**	**18.0**	**13.6**	**8.9**	**3.9**	**-0.6**	**7.9**
Agrometeorological station	**Average monthly maximum temperature (°C)**												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual average
Adamclisi	3.9	6.3	10.9	16.7	22.6	26.8	29.5	28.6	24.4	18.8	11.5	5.6	17.2
Corugea	2.7	5.2	10.1	16.1	22.1	26.5	29.1	28.1	23.6	17.2	10.5	4.3	16.4
Constanța	3.8	5.5	8.3	13.9	19.7	24.6	27.0	27.0	22.3	16.7	11.0	5.6	15.5
Mangalia	5.5	6.7	8.7	13.9	19.6	24.7	27.1	27.1	22.5	17.4	12.2	7.1	16.1
Medgidia	4.2	6.5	10.9	16.1	22.5	26.9	29.5	29.5	24.3	18.2	11.7	5.9	17.2
Tulcea	5.9	6.3	10.8	16.9	23.1	27.3	29.8	29.8	24.1	17.8	11.2	5.6	17.2
Continental Dobrogea average	**4.0**	**6.3**	**10.3**	**15.7**	**21.6**	**26.2**	**28.7**	**28.7**	**23.5**	**17.6**	**11.4**	**5.7**	**16.6**

Source: processed data according to NMA, 2025 [1].

Typically, these monthly maximum temperatures are recorded across almost the entire studied agricultural area, influenced by the Western circulation and the intrusion of the Southern and continental air masses. Additionally, in terms of maximum air temperatures, a thermal uniformity is observed in July and August across the six analyzed agrometeorological stations.

The averages of monthly minimum temperatures show low values, below 0°C, during the three winter months, ranging from -3.9°C (Corugea) to -0.9°C (Mangalia), which are typical limits for this period (Table 2). The temperature factor plays a particularly important role in the physiological processes of plant organisms. Thus, the maximum and minimum average air temperatures have a significant impact on the proper development of plants.

During the winter season, due to unfavorable temperatures, winter crops can suffer frost damage caused by low temperatures and the absence of a snow cover. If the plant's tillering node is damaged, when the air temperature rises after a period of very low temperatures, a false resumption of vegetation occurs. In addition to the frost damage to plants, seedling heaving can also occur, caused by the alternation of positive and negative temperatures, which leads to repeated freezing and thawing cycles [5]. Subsequently, due to these phenomena, plant death may occur, leading to a decrease in the agricultural production at the end of the season.

Maximum air temperatures exceeding the critical biological resistance threshold of winter wheat lead to the occurrence of the shriveling phenomenon. This phenomenon represents the process by which the transport of substances assimilated in the leaves to the grain is prevented. As a result of this phenomenon, winter wheat stops growing, also suffering the yield of the crop.

Spring index

Between February 1st and April 10th, the thermal regime fluctuations occur, with variations from year to year, impacting both the resumption of vegetation and the execution of agricultural fieldwork.In general, the temperature increases at the end of winter (February),being beneficial forthewinter wheat, leading to the vegetation resumption, phenological advancement and an accelerated rate of dry matter accumulation in the grain [11].

The spring index represents the thermal potential of the transition period from winter to spring and is calculated for the period between February 1st to April 10th [1]. This index characterizes the thermal conditions required for the winter crops.For the period 1991–2023 (Fig. 3), the multiannual average of the spring index has recorded normal values, ranging from 307.6 (Corugea) to 382.1 (Tulcea), the’heat units’ indicating a normal spring transition (301–400 'heat units'). The exception was the Constanța agrometeorological station, where 403.2 'heat units' were recorded, classifying the spring transition as early (401–500 'heat units'). Although the multiannual average remained within normal limits, the variability of the spring index revealed years in which the threshold of 500 'heat units' was exceeded, indicating a very early spring transition (> 500 'heat units').

Fig. 3. Heat units ($\Sigma T_{med.} > 0°C$) at the agrometeorological stations analyzed for the period1991 – 2023: Adamclisi (top left), Constanța (top right), Corugea (middle left), Mangalia (middle right), Medgidia (bottom left) and Tulcea (bottom right).
Source:processed data according to NMA, Agrometeorological Service, 2025 [3].

The maximum values of the spring index were recorded in 2016, ranging from 522.7 'heat units' (Corugea) to 651.7 'heat units' (Constanța).
These maximum values, recorded between February 1st and April 10th, 2016, reflect higher-than-usual daily average temperatures for this period, which led to a phenological advancement of winter wheat crops in the analyzed region, intensifying the vegetative growth rates. In the case of a very early spring transition, when the phenological phase of stem elongation occurs earlier, the period of dry matter accumulation in the grain is extended, leading to a higher yield [14]. In 2016, due to the intensified biological rhythms, the recorded yield in the studied region was 4,037 kg/ha, a significantly higher production compared to 2003 (296 kg/ha). The lowest values of the spring index were recorded in the years 1996 and 2003.The lowest value of the spring index in the period 1991–2023 was recorded in 2003 (103 'heat units') at the Corugea agrometeorological station, indicating a late spring transition.Thus, in this year, a slow evolution of vegetative rhythms was recorded due to lower-than-usual temperatures, which was reflected in the low yields of 2003 (296 kg/ha).

CONCLUSIONS

This study has analyzed the evolution of the productions obtained at the end of the growing season of winter wheat, in relation to the influence of air temperature on winter wheat crops.
The variability of winter wheat yields, in terms of the thermal regime, in the Continental Dobrogea region was significant.The low values of winter wheat productions in 2003 (296 kg/ha) were due to the unfavorableair temperatures recorded during the critical periods of winter wheat, which was also reflected in the values of the spring index (late spring). Thus, this year, there was a slow evolution of the biological rhythms of plants, due to lower temperatures than usual. Depending on the variability of thermal resources and the failure to meet optimal air temperature requirements in the critical May-June period, winter wheat yields in 2003 decreased compared to those recorded in the period 1991–2002.
The year 2018 was characterized by the highest productions obtained in the entire region (5,133 kg/ha). This was due to moderate temperatures during the winter and a thermally favorable spring, which was also reflected in the spring index values of this year.To maximize the agricultural yields, a detailed analysis of the available thermal resources is necessary. This process is essential for the proper management of crops, based on the climatic conditions characteristic of each period.

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