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STUDIES REGARDING THE INFLUENCE OF THERMIC AND HYDRIC STRESS ON PREMIUM WHEAT YIELD DURING 2006-2012 IN SOUTHERN, CENTRAL AND NORTHERN PARTS OF ROMANIA

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Abstract

The paper aims to present in detail the results of the researches performed in order to determine how weather conditions could affect winter wheat yields. To achieve this purpose we used several measurements and observations from our working points Modelu – Calarasi, Poroschia – Alexandria and also from various locations in Central and Northern Romania, data that were analyzed under different aspects. We took into account the quantity of rainfall during the flowering stage (in spring) and the temperature, expressed in °C, which exceeded the limit of 30°C in the same vegetative stage, being known that this is the maximum value supported for a normal behavior of premium wheat plants, of their production and of grain quality. Data obtained from our own experimental fields, as well as those collected from other sources, showed a negative correlation between the quantity of fallen rain and the high temperatures, but also two opposites correlations between precipitations and crops (positive links up to 350 mm and exponentially negative afterwards). Another negative correlation that we registered it is the one between the amount of degrees above 30°C recorded during flowering and the production level (which decreased, sometimes by up to 50%). The weakest results in the premium wheat production were obtained when soil drought, atmospheric drought and thermal stress correlative worked together, thing that began to happen more often in the last 10 years, especially in the Romanian Plain and in all the southern part of the country.

Key words: *premium wheat, drought, varieties, yield, genetics.*

INTRODUCTION

Climate changes are reflected by a significant modification of abiotic factors which acts on plants. Extremely important in this category are the temperature and the water (Berca, 2011). At the intersection between water and temperature is the humidity. Wheat crop begins to be under stress if soil moisture is approaching the withering coefficient, but also if the humidity goes below 30%, which is the minimum accepted (Meluca et al., 2011). It had been shown on correctly studied models (Brown and Rosenberg, 1999) that by simply increasing the area temperature with 1°C the production of wheat decreases by 18%, so that when it rises with +2.5°C it falls by 20% (temperature over 30°C). Starting from many factors solutions are seeked for taming the abiotic factors aggression on agriculture (INCDA Fundulea). Researchers calculate the climate impact on wheat yield beginning with the determination of evapotranspiration (Ehteramian, 2012), the losses of production caused by water / temperature stress exceeding 57%.

MATERIALS AND METHODS

In the research fields and lots in Southern Romania – Modelu, Alexandria County, in Center – Zagar area (Mures County) and in Northern part – Diosig (Bihor) was cultivated an extremely various range of varieties, out of which were selected 5 Premium varieties and „A” for the analysis of genetic composting plant (Capo, Josef, Fulvia, Balaton).

The following parameters were measured:

- total amount of temperature degrees that exceeded 30°C in May and June, which included 100% the flowering period;
- total amount of rainfall in the experimental year and area;
- in the South zones was also determinated the relative air humidity during flowering stage;
- productions level at 14% humidity, expressed in q/ha.

The data obtained were statistically processed through analysis (dispersion) and were presented as tables and graphs. Was studied the correlation between the amount of temperatures above 30°C (ΣT>30°C) and the crop yield, of precipitations on yields and of trifactorial correlation expressed in 3D between temperatures of over 30°C, precipitations and crop yields.

Were also made directly observations into large farms, with high technologies, in order to check the results from experimental fields and verification lots.

A special accent was put on the agricultural year 2011-2012, which registered the highest scorching heat of the last 50 years. Where lacked the possibilities of climatic parameters measuring, the evaluations were made with marks from 1 to 9, namely:

- 1-2 = very resistant
- 3-4 = resistant
- 5-6 = medium resistant
- 7-8 = sensitive
- 9 = very sensitive.

RESULTS AND DISCUSSIONS

Was established that 2012 was a very suitable year for testing the varieties resistance not only in Romania, but also in the entire Europe. In April 2012 at Stockerau, in Austria, were communicated the wintering behavior results of main cereals. It turned out that especially barley varieties, as well as those of Durum wheat, weren't affected by the hardness of winter, with temperatures reaching –25°C for more than 8 days in a row, as they were by the late and harsh frosts from early and mid April.

The results from Pannonian Plain, an area with a similar climate to that of Southern Romania, revealed average yieds, slightly over 3000 kg/ha, mainly because of the recorded thermic stress. The studies carried out during 2004-2010 by Boku University of Vienna on 55 researches (Grausgruber, 2012) show that, in such conditions, the average productions for 19 varieties is situated at 58 q/ha in dry areas and 53 q/ha in wet areas. No pesticides were applied. In Northern and Western regions the productions increased up to 65 q/ha, the summer thermic stress being greatly reduced.

The contribution of genetics remains decisive in the adjustement reports between wheat plants and the new stress conditions from soil and atmosphere. Investigations conducted during 1972-2008 in Pannonian Plain, using 473 researches and a number of almost 50 varieties (BauernZeitung, 2009), demonstrated that, despite the increasing of abiotic stress indicators, the varieties productivity for the studied period (36 years) grew with 30.5 kg/an (Figure 1). The effect of genetics wasn't equal every year, it ranged from 0.3 to 1.2%.

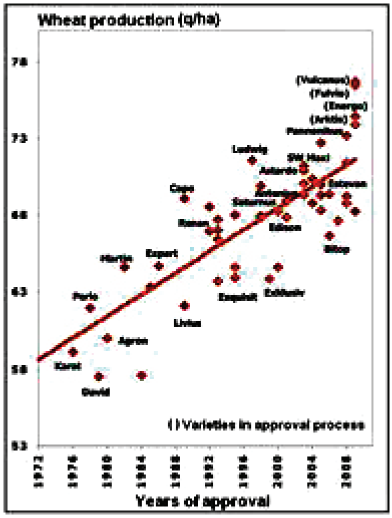

Figure 1. Certified varieties and some recently removed from culture – resu1ts 1972-2009, 473 researches

The analysis of wheat average yields in Romania between 2000-2012 (Figure 2), in spite of an advanced technology introduced in agriculture, reveals a slight increase from 2518 kg/ha in 2000 down to 2660 kg/ha in 2009, after which it remains relatively constant until 2012 (also see Figure 3).

The real values, included in Figure 2, demonstrate a very large variation on the country average yield from one year to another. If the arithmetic mean of the 12 analyzed years indicate a value of 2565 kg/ha, the variation coefficient is 28.39% (Table 1). It means that the average yield along the 15 years has been set in the confidence interval 2565 ± 28% = [2565 x 1.28 → 2565 x 0.72] = [1846 → 3283].

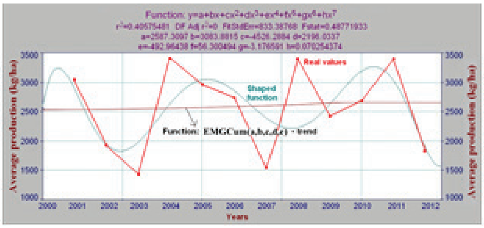

Figure 2. The dynamics of wheat average productions in Romania between 2000-2012 (original)

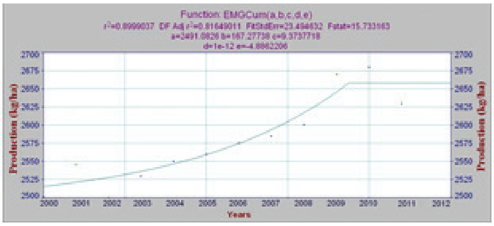

Figure 3. The corrected dynamics of wheat production during 2000-2011, in Romania (original)

Table 1. Variation in wheat production in Romania, 2001-2012 (national average)

No.	Inputs	Frequency	Amount
1	1,429.00	1	1,429.00
2	1,541.00	1	1,541.00
3	1,830.00	1	1,830.00
4	1,924.00	1	1,924.00
5	2,421.00	1	2,421.00
6	2,685.00	1	2,685.00
7	2,746.00	1	2,746.00
8	2,965.00	1	2,965.00
9	3,038.00	1	3,038.00
10	3,394.00	1	3,394.00
11	3,403.00	2	6,806.00
TOTAL		12	30,779.00
RESULTS			
ARITHMETIC MEAN =			2,564.91
MEAN DEVIATION =			613.26
SQUARE MEAN DEVIATION =			530,321.17
STANDARD DEVIATION =			728.23
VARIATION COEFFICIENT =			28.39 %

The exceptions encountered in 2003 and 2007 (Figure 2), which significantly fall under the calculated interval, are extremely important for our analysis because the reduction of production wasn't at all due to technological factors, but primarily to thermic and hydric tensions. Researches made in the years of study in 4 Romanian zones (Alexandria, Modelu – Calarasi, Zagar – Mures and Diosig – Bihor) show that both high temperatures and low rainfall were able to have a negative influence on wheat harvests.

When referring to the temperatures level, very harmful proved to be the quantities of heat, expressed in Σ^{o}C, from May-June and particularly from flowering stage (Figure 4).

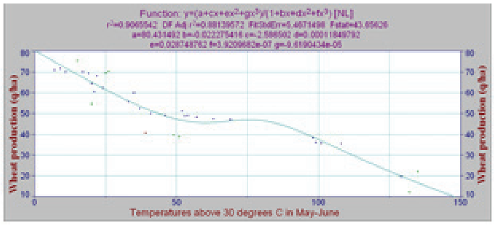

Figure 4. Influence of over 30 oC temperatures in May-June (blooming) on wheat yield (original)

Accumulating 50^{o}C over the daily 30^{o}C acceptated as maximum in wheat crop have led to a production decrease of 3 t/ha. Increasing with other 50^{o}C above 30^{o}C is reducing the yield level with another metric ton/ha, so that at >Σ150^{o}C the harvest is almost compromised.

Usually the thermic stress complement the one caused by the lack of water. There is a negative correlation between the water scarcity and thermic stress, known and monitored by all agrometeorological stations and institutes.

Scientists from Fundulea (Petcu, 2007), talking about the term of „scorching heat", explain that at high values of it we are dealing with a mixed stress – hydric and thermic –, which leads, at cellular level, to an oxidative degradation.

The studies made in order to show wheat drought resistance demonstrate the induction, at cellular level, of protective enzymatic systems against oxidative stress. Oxidative stress reduces the FSI (foliar surface index), which is positively correlated with photosynthesis. FSI damage leads to the reduction of biomass and/or to the losses in plant productivity.

Although generally it is stated that the wheat is a high tolerance plant to hydric deficit, this applies for most of the autumn-winter season, all plants becoming susceptible in early spring, during the production parts differentiation, ie at flowering – grains filling, in May-June. These are, usually, rainy months, which should bring into soil the needed water for a constant yield. In fact, the annual rainfall variation has become extremely important, in some years (such as

2003, 2007, but also 2012) affecting the majority of wheat genotypes cultivated in Romania.
In Figure 5 is presented the relation between the level of rainfall in Romania and the wheat yield, figures obtained due to measurements and observations realised in our experimental and demonstrative fields.

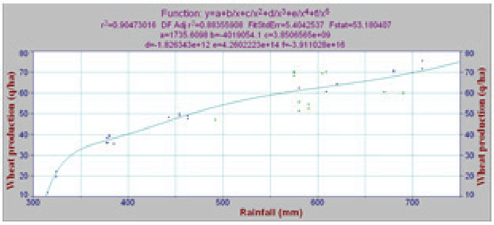

Figure 5. Correlation between precipitations (mm) and wheat production level in Romania (original)

The calculation shows that wheat production tends toward compromise in areas where annual rainfall drop below 300 mm, water stress not being well supported by wheat plants. Only from 360-380 mm we can say (especially if 70% of the precipitations fall during wheat vegetation period – in spring and early summer) that under high agrotechnics, with full water conservation, we can produce 3500-3800 kg/ha. In the same conditions, at 450 mm we can reach to about 5000 kg/ha, at 600 mm to 6200-6500 kg/ha and at 700 mm to 6800-7200 kg/ha.
The 3D analysis of the influence of rainfall and of the temperature amount over 30°C in May-June is the one presented in Figure 6.

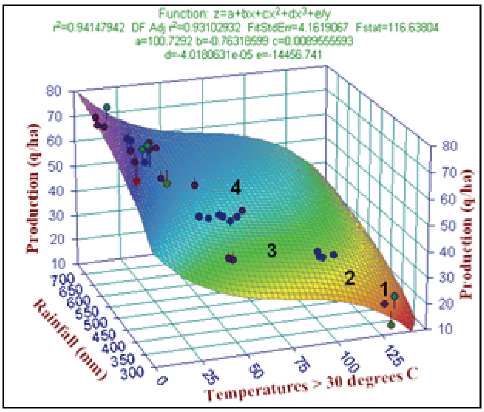

Figure 6. How is wheat production affected by high temperatures and rainfall level (original)

Depending on those 2 parameters we can distinguish 4 event areas of wheat:

- a critical area from Σ75°C more than 30°C during flowering period and rainfall between 300 and 450-550 mm (last ones at amounts above 125°C) - yields are around 2000-2500 kg/ha;
- a sub-critical area from Σ45-50°C to 75°C and annual rainfall of 450-500 mm - yields up to 4000 kg/ha;
- a favorable area from Σ25-45°C and rainfall not more than 650 mm - yields up to 5000 kg/ha;
- a very favorable area from Σ0-25°C and annual rainfall of about 650-700 mm - yields up to 8000 kg/ha.

This division of wheat production favorability areas by humidity and supra-temperatures needs revision according to the increase of research years. The pattern is valid for the average of at least 16 varieties of various origins (Romanian and foreign), with a high variability of production dictated by many other factors, but in which the genotype remains an important element.
2012 was a year characterized by low rainfall and extremely high temperatures all over Romania, but mainly in the South. The data provided by the Ministry of Agriculture show a reduction of 20% on wheat production, while farmer’s organizations are declaring to the press that the losses caused by hydric and thermic stress are around 40%. Our observations indicate that the crop losses were closely correlated with the super-temperatures from flowering time, with the overlapping of both processes and with soil drought. The relative air humidity has also played an important role (Figure 7).
The number of days with air humidity below 30% ranged between 24-35 in 2007, 18-26 in 2008, 15-23 în 2009, 5-14 in 2010 and 39-44 in 2012, according to data collected from meteorological stations in Alexandria and Calarasi. Low humidity in the atmosphere, correlated with high temperatures and with a low water content of the soil, are working together to achieve maximum hydric stress – with extremely high destructive effect on yield, which in many cases, as it were 2007 and 2012, are going till the compromise of the harvest.

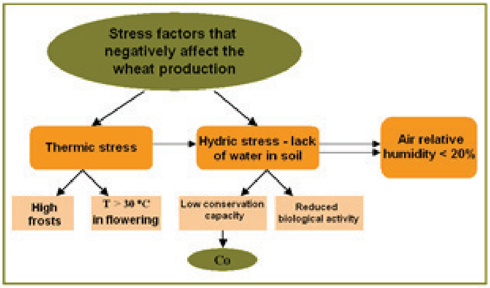

Figure 7. Thermo-hydric stress factors on winter wheat and other cereals (original)

Negative thermic stress from winter may largely affect the harvest, especially on barley. In 2011-2012 winter, one of the harshest in the last 20 years, in Eastern part of Romania, especially in Braila, Galati, Vaslui counties, barley crops were over 50% destroyed. However, there were varieties that have resisted, but also of those that were completely destroyed by frosts.

Agronomically speaking, the studies (Oberforster, 2012) show that the damages occuring on cereals in winter come from two directions (Figure 8).

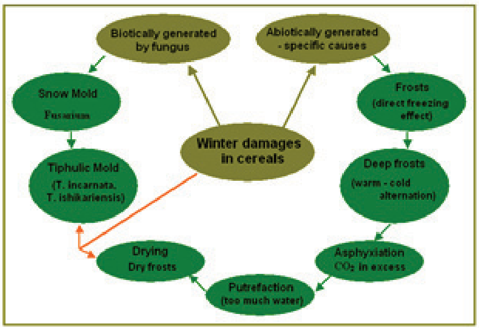

Figure 8. Causes of winter damages on grains – processed after Oberforster (2012)

The effect of the causes presented above is the level of productions that also include, in addition to their natural inputs and anomalies, a large amount of technological inputs.

At Modelu – Calarasi, in experimental plots in which the entire technology has been kept at maximum level, 15 Premium genotypes, which in normal years gave similar yields, in 2012 varied from 1 (Balaton variety) to 1.8 (Atrium variety) (Table 2).

Table 2. Thermic stress effect on Premium wheat yield (Modelu, 2012)

Variety	Production		Difference		Semnifi-cation
	kg/ha	%	kg/ha	%	
Balaton	4,886.00	71.25	-1,971.53	-28.75	000
Atrium	8,601.00	125.42	1,743.47	25.42	***
Arnold	7,447.00	108.60	589.47	8.60	**
Fabula	7,497.00	109.33	639.47	9.33	**
Fulvio	7,665.00	111.77	807.47	11.77	***
Josef	6,491.00	94.66	-366.53	-5.34	
Bitop	6,395.00	93.26	-462.53	-6.74	0
Midas	7,365.00	107.40	507.47	7.40	*
Peppino	7,210.00	105.14	352.47	5.14	
Pireneo	6,371.00	92.91	-486.53	-7.09	0
Capo	7,162.00	104.44	304.47	4.44	
Philipp	6,994.00	101.99	136.47	1.99	
Astardo	6,970.00	101.64	112.47	1,64	
Pedro	5,665.00	101.64	112.47	1.64	000
Ludwig	6,144.00	89.59	-713.53	-10.41	000
Average	6,857.53	100.00	0.00	0.00	CONTROL
DL 5% = 393.7472 DL 1% = 525.9086 DL 0.1% = 688.1778					

Balaton variety, with 8-10 days more untimely, normally obtains similar yields with Atrium. In 2012 its earliness was a disadvantage because all these days were during full flowering period, the effect on production being drastically negative.

Late flowering of Atrium variety and of others with similar genom came after a rain of 15 mm, which reduced the temperatures below 30°C for a period long enough, so the flowering and the process of grains formation and filling were held in normal conditions.

Components like in Atrium we also found in Fulvio, Fabula, Arnold and Midas.

In Central areas, such as Zagar – Mures, due to lower stress conditions, the output variation is lower, ie of 1–1.26, that is 3 times less that in South part of the country, at Modelu (Table 3).

Very good behavior have had, in this area, the varieties Pireneo, Astardo and Pedro, while Philipp, Josef and Fabula reacted weaker. All these happened in yields over 5200 kg/ha, on a low variation, so its difficult to draw a conclusion about the proper Premium genotyp for this region.

In Northern Romania, at Diosig – Bihor were performed researches with a number of over 20 varieties of different origins (Table 4).

Table 3. Thermic stress effect on Premium wheat yield (Zagar, 2012)

Variety	Production		Difference		Semnifi-cation
	kg/ha	%	kg/ha	%	
Balaton	5,720.00	96.42	-212.50	-3.58	
Arnold	5,810.00	97.94	-122.50	-2.06	
Fabula	5,440.00	91.70	-492.50	-8.30	0
Josef	5,250.00	88.50	-682.50	-11.50	00
Bitop	6,030.00	101.64	97.50	1.64	
Midas	6,160.00	103.83	227.50	3.83	
Peppino	6,020.00	101.47	87.50	1.47	
Pireneo	6,640.00	111.93	707.50	11.93	***
Capo	5,910.00	99.62	-22.50	-0.38	
Philipp	5,390.00	90.86	-542.50	-9.14	00
Astardo	6,480.00	109.23	547.50	9.23	**
Pedro	6,340.00	106.87	407.50	6.87	*
Average	5,932.50	100.00	0.00	0.00	CONTROL
	DL 5% = 326.0527				
	DL 1% = 391.6491				
	DL 0.1% = 525.5430				

Table 4. Wheat behavior in the North part of the country (Diosig Bihor, 2012)

Variety	Production		Difference		Semnifi-cation
	kg/ha	%	kg/ha	%	
Saggitario	4,399.00	75.50	-1,395.71	-24.50	000
Apache	5,481.00	96.23	-214.71	-3.77	
Arlequin	6,029.00	105.85	333.29	5.85	
Renan	5,821.00	102.20	125.29	2.20	
Jindra	5,575.00	97.88	-120.71	-2.12	00
Exotic	5,008.00	87.93	-687.71	-12.07	
Cubus	5,859.00	102.87	163.29	2.87	
Lupus	5,462.00	95.90	-233.71	-4.10	
Lukullus	5,575.00	97.88	-120.71	-2.12	
Gallus	5,991.00	105.18	295.29	5.18	
Pannonikus	6,067.00	106.52	371.29	6.52	
Vulcanus	6,067.00	106.52	371.29	6.52	
Amicus	5,940.00	104.29	244.29	4.29	
Sorrial	6,407.00	112.49	711.29	12.49	**
SO-207	5,934.00	104.18	238.29	4.18	
Element	5,934.00	104.18	238.29	4.18	
Bitop	5,273.00	92.58	-422.71	-7.42	0
Midas	6,161.00	108.17	465.29	8.17	*
Boema	5,594.00	98.21	-101.71	-1.79	
Glosa	5,821.00	102.20	125.29	2.20	
Crisana	5,311.00	93.25	-384.71	-6.75	
Average	5,695.71	100.00	0.00	0.00	CONTROL
	DL 5% = 413.8476				
	DL 1% = 550.4173				
	DL 0.1% = 715.9564				

The variation coefficient is higher than in Mures, but much smaller than at Modelu (1–1.45). Is also higher the genotypes variability because they come from very different sources, not having common genitors, except perhaps Midas and Bitop varieties. Thermic stress was higher in Bihor than in Mures.

An excellent behavior had the varieties Sorrial and Midas and a negative one was found in Saggitario, Exotic and Bitop. Phenomena is happening on an average of almost 5700 kg/ha. We need to mention that the average yields per areas were much lower thn those obtained in the experimental fields (Figure 9).

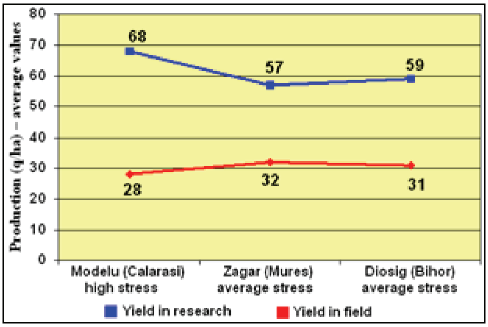

Figure 9. Wheat productions in 2012 in different parts of the country under stress influence (original)

In South Romania the level of average yields obtained from agricultural departments on normally kept surfaces is 2 times smaller than the one obtained in research, while for Mures and Bihor the differences are about 2500 kg/ha. The gap between research and production is not related only by abiotic stress, but also by technological level, with particular reference in crop rotation, soil tillage and fertilization.

CONCLUSIONS

XXIst century started with at least 4 years on which the thermo-hydric stress put its deeply negative mark on Romania's average productions, but also on them level and quality, even in units well-equiped technically and managerially.

Specialized research can make more resistant varieties to any kind of thermic and hydric stress (– or +), but can't be created varieties (genotypes) to completely resist to the total lack of water.

In Romania is grown a large assortment of variables genotypes as resistance. The research has the possibility to make a selection of the most effective ones for a fair and efficient promotion.

Extremely dangerous are the alternations between very high frosts and repeated warming periods, that are blocking the genetically defense sistem of the plant.

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