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Weather Conditions and Yield of Wheat in Bosnia and Herzegovina with Emphasis on Climatic Change and Tuzla Canton

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Authors' contributions

This work was carried out in collaboration between all authors. Authors MM and VK designed the study, managed collection of meteorological data, wrote the protocol and wrote the first draft of the manuscript. Authors MB, BS and MR managed statistical data. Author JJ managed literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this study was to test the impact of monthly precipitation and temperature regimes on winter wheat yields in Bosnia and Herzegovina (B&H) for the last 15-year period (2000-2014) with an emphasis on its administrative parts Federation of B&H (FB&H) and Tuzla Canton (TC: from 2005-2014 period). Winter wheat is an important field crop in B&H, but yields are low, (average of 3.24 t ha^{-1}) with very high variation among years (from 2.26 to 3.92 t ha^{-1}). We estimated that yield differences are mainly due to weather variability. Average temperature in Tuzla (October-June) was 8.3℃ in the last 15 years or 0.9℃ higher than the 1 961-1990 and 1925-1940 averages.

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Precipitation close to the 30-year average (663 mm, 642 mm and 636 mm) and their balanced monthly distribution characterized three growing seasons favorable for wheat (2007/2008, 2008/2009 and 2012/2013, respectively). Also, the temperature regime was without excessive cold or warm periods in these years. Under these conditions, wheat yields were considerably higher (3.7, 3.8 and 3.9 t ha^{-1}, respectively) than in three estimated unfavorable years (2002/2003, 2009/2010 and 2013/2014 with 2.3, 2.7 and 2.9 t ha^{-1}, respectively). Weather deviations as either drought or excessive precipitation in combination with high temperatures characterized estimated less favorable years. Tuzla Canton had about 5% of the national wheat harvested area, whereas yields were somewhat higher compared to the country average. Although it is evident that yields of wheat and weather conditions in B&H are very different between years, by performing simple correlation analysis there was found a minimal connection of precipitation and temperature with yields. Significant negative correlations were found only in level TC between yields and monthly values of precipitation in April (-0.88**), May (-0.70**) and total precipitation (-0.73**). Also, significant positive correlations were found between April (0.76**) and May (0.62*) temperature and yields.

Keywords: Bosnia and Herzegovina; climatic change; grain yield; precipitation; temperature; winter wheat.

1. INTRODUCTION

Global warming and more frequent extreme weather conditions are oft connected with climate change. Annual global temperatures have increased by about 0.4℃ since 1980 [1].

This phenomenon has often adverse influence on the quantity and quality of field crop yields. Lobell and Field [2] estimated that about 30% of variations of global average yields for the world's most widely grown crops are the result of growing season precipitation and temperature variations.

Winter wheat is an important field crop on the arable lands of Bosnia and Herzegovina (B&H). In general, yields of wheat in this area are low and highly variable over the years. In the 2000-2014 period, the average wheat harvested area in B&H was 74.67 thousand hectares with average grain yield of 3.24 t ha^{-1} and yearly variation from 2.26 to 3.92 t ha^{-1} [3].

Weather conditions during the growing seasons are the main reason for variation in annual yields in the period considered. In neighboring Croatia [4] and nearby Hungary low wheat yields are associated mainly with either excessive or low precipitation [4-5]. Under the environmental conditions of Eastern Croatia, there are indications that low wheat yields are mainly in connection with precipitation excess, especially during autumn/winter period. Pepo and Kovacevic [5] reported an impact of weather conditions on wheat yield in the eastern part of Hungary and Croatia for the 1990-2009 period. Water deficit was an important environmental problem for wheat production in eastern Hungary; there was positive correlation between precipitation in spring and wheat yield, and negative correlation between temperature in spring and the yield of winter wheat [5].

Beside soil and weather conditions, many other factors influence wheat yields. These include crop rotation, tillage, fertilization, crop protection, variety etc.

Weather conditions also have an important role for maize growing. Majdancic et al. [6] found considerable variation in maize yield in Federation of B&H (FB&H) and Tuzla Canton (TC) in the 2000-2014 period. Average grain yields of maize in FB&H was 3.99 t ha^{-1} with variation among the years from 2.18 to 4.92 t ha^{-1}. In three unfavorable years yield was below 3.0 t ha^{-1}, while in three favorable years it was above 4.5 t ha^{-1}. Precipitation in the April-September period of unfavorable years in Tuzla was 320 mm (3-year average) while in the favorable years it was 492 mm. Mean air-temperature in the favorable years was 17.5℃ (1.0℃ lower than in the unfavorable years). In general, the 2012 growing season was especially unfavorable for maize in B&H and countries of the region. Affected by drought and high temperatures, particularly in August, maize yields in B&H and neighboring countries were 38 to 53% lower than in favorable 2010 [7]. Adequate fertilization contributes to alleviation of drought stress [8].

The aim of this study was to test the impact of monthly precipitation and average air-

temperature regimes on winter wheat yields in B&H for the last 15-year period (2000-2014) with an emphasis on its administrative parts FB&H and Tuzla Canton and on climate change.

Justification of this study is in importance of wheat, as main field crop, for agriculture, food processing and economy of B&H and low utilization of genetic potential of available wheat varieties because of environmental stress limitations, mainly soil acidity, low nutrient supplies and unfavorable weather conditions. Through adequate soil and crop management, it would be possible to alleviate stress induced by weather variations.

2. MATERIALS AND METHODS

2.1 Collection and Analysis of Data

The FAO data base [3] and publications of Institute for Statistics in Sarajevo [9-12] were used as the sources of wheat harvested area and yield data, while publications of the Federal Hydrometeorological Institute [13] were perused for the meteorological data (monthly values of precipitation and average air temperatures) for Tuzla (44°32' N and 18°41' E).The long-term values of precipitation and temperatures (1925-1940 and 1961-1990) were shown in the other studies [14,15].

Estimation degree of favorable and unfavorable weather conditions in individual growing season of wheat was made based on the published [3, 9-12] annual yields. With aim of scientific evaluation of weather and yield data, simple correlation analysis was performed using Minitab® Statistical Software [16]. Monthly and 3-month data of precipitation and mean air-temperature in Tuzla were correlated with yields.

2.2 Description of the Analyzed Area

B&H is a country in Southeastern Europe located on the Balkan Peninsula, bordered by Croatia to the north, west, and south, Serbia and Montenegro to the east. In the central and eastern interior of the country, the terrain is mountainous while in the northwest, it is moderately hilly and in the northeast, predominantly flat. The inland is a large region with moderate continental climate, characterized by hot summers and cold and snowy winters. The southern tip of the country has a Mediterranean climate and plain topography.

B&H is administratively divided in two political entities (FB&H and Republic of Srpska or RS) and Brcko district. The FB&H consists of 10 autonomous cantons having their own governments.

FB&H covers a land area of 26,110 km^2 much of which is covered by forests, while the northern lowland area and the northern part of TC are suitable for intensive field crop production.

TC is one of ten cantons of FB&H and it covers 2649 km^2 or 10.14% of FB&H and 5.30% of B&H territory. Agricultural area represents 49% of the total TC territory. TC is situated in the northeastern part of B&H (Fig.1). Climate in TC is temperate continental with marked differences among winter, spring, summer and autumn periods and average annual precipitation 895 mm and air-temperature 10.0°C (1961-1990). The coldest month is January (-0.8℃), whereas the warmest (19.3℃) is July [17].

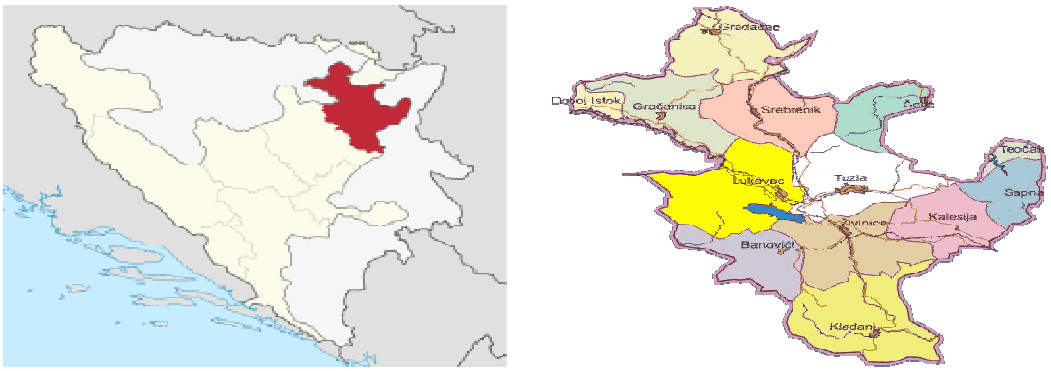

Fig. 1. Administrative division of B&H in (the left) level of entities (light colored is FB&H) + situation of TC in FB&H (the red colored); map of TC municipalities (the right) [17]

TC covers about 10% of FB&H. However, this canton contains 8.2% and 20.4% of arable land in B&H and FB&H, respectively, and 4.6% and 16.9%, respectively, of wheat-growing area (Table 2). About 48% of arable land and gardens are unfarmed in FB&H, while in TC this contribution is about 29% [9-12].

3. RESULTS AND DISCUSSION

Weather conditions, mainly precipitation and temperature regimes, considerably affect the grain yield of winter wheat. With that regard, as typical example of close to ideal and extremely unfavorable years for wheat growth are data of Djakovo State farm (Table 1). Under practically identical soil and crop management conditions of State Farm Djakovo, in two divergently different growing seasons with aspect of weather conditions, yields of wheat were 7.30 and 4.50 t ha^{-1}, respectively (Table 1). Moderate and equalized monthly distribution of precipitation, accompanied with mild winter and absent of extremely either too cold or too warm temperatures, are main characteristics of close to ideal 1989/1990 growing season. On the other hand, excessive precipitation, particularly in autumn and in grain filling period (promotive factor of leaves and ear diseases), as well as colder winter, characterized unfavorable 1993/1994 growing season. These parameters could be used as criterion for estimation of more favorable and less favorable years with aspect of wheat growth in our study.

Average wheat yield in the analyzed 15-year period in B&H was 3.24 t ha^{-1}, which is low with respect to genetic potential of wheat and moderate continental climate characteristics. The main reasons of low yields in B&H are unfavorable soil physical and chemical characteristics with a small proportion of land with hydro- and agromelioration and in addition to inadequate soil and crop management practice [19,20]. However, considerable variation in wheat yields was recorded in B&H (2.26 to 3.92 t ha^{-1}), FB&H (2.2 to 4.0 t ha^{-1}) and TC (2.4 to 4.7 t ha^{-1}) (Table 2). These yield differences were mainly induced by specificity of weather conditions during individual growing seasons. The average temperature in Tuzla was 8.3℃ in the last 15 years or 0.9℃ higher than the 1961-1990 average, while variability in precipitation increased among years (Table 3).

Based on yields, the 2002/2003, 2009/2010 and 2013/2014 growing seasons were unfavorable (3-year averages 2.6, 2.7 and 2.7 t ha^{-1} in B&H, FB&H and TC, respectively), while the 2007/2008, 2008/2009 and 2012/2013 growing seasons were favorable for wheat growth (3.8, 3.9 and 4.5 t ha^{-1}, respectively).

In general, low precipitation (486 mm), cold January and February and warm May and June were the main characteristics of the 2002/2003 growing season. Water deficit was especially found in February-April period (total of 82 mm precipitation only). Excessive precipitation of 1095 mm and moderate temperatures characterized the 2009/2010 growing season. Distribution of precipitation was also unfavorable because about half of precipitation fell in the last three months. The 2013/2014 growing season was characterized by a long drought period (December-February: 70 mm) and excessive precipitation in April-May (even 526 mm), while the temperature regime was around average. Unfavorable weather conditions in these three years resulted in low wheat yields in B&H (2.3, 2.7 and 2.9 t ha^{-1}, respectively), FB&H (2.2, 2.9 and 3.1 t ha^{-1}, respectively) and TC (3.0 and 2.4 t ha^{-1} for 2010 and 2014, respectively). Low and unbalanced distribution of precipitation was evidenced as detrimental factor of wheat yield also by the other studies [21-23].

Precipitation close to the 30-year average (663 mm, 642 mm and 636 mm) and their balanced monthly distribution characterized three growing seasons favorable for wheat (2007/2008, 2008/2009 and 2012/2013, respectively). Also, the temperature regime was without excessive cold or warm periods in these years. Under these conditions, wheat yields were relatively high (respectively, 3.7, 3.8 and 3.9 t ha^{-1} in B&H, 3.8, 3.9 and 4.0 ha^{-1} in FB&H and 4.3, 4.6 and 4.7 ha^{-1} in TC) than in three less favorable years.

By comparison of climate in 1961-1990 and 1925-1940 periods, mainly slightly differences of monthly precipitation and temperatures were found. Period 1961-1990 were characterized by the colder November for 1.3℃ and June for 0.8℃, while December, February and March were warmer for 0.7℃, 1.4℃, and 0.5℃, respectively. However, average data of 2000-2014 period showed trend of warming because average temperature in October-June period were higher for 0.9℃ compared to 1925-1940 and 1961-1990 periods. The mean air-temperature in the coldest January in 2000-2014 period was higher by 1.6℃ (Table 3).

Table 1. Precipition and temperature in two divergently growing seasons for wheat growth

Precipitation (mm) and mean air-temperature (°C) in Djakovo											
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Febr**	**March**	**April**	**May**	**June**	**Total**	**Average**
The 1989/1990 growing season: estimated close to ideal for wheat growth (yield on State Farm Djakovo 7.30 t ha^{-1}; 7220 ha of harvested area)											
mm	46	30	24	19	40	29	47	52	61	348	
℃	11.3	4.8	2.5	0.4	6.6	9.2	11.2	17.8	19.9		9.3
The 1993/1994 growing season: estimated as unfavorable for wheat growth (yield on State Farm Djakovo 4.50 t ha^{-1}; 6070 ha of harvested area)											
mm	57	132	110	65	47	51	69	24	184	739	
℃	13.0	1.8	2.1	2.6	1.8	9.8	11.9	17.1	20.3		8.9

Source: [18]

Table 2. Arable land and areas covered by winter wheat

Arable land and gardens (ArLG) , wheat harvested area (WHA) and yields									
Wheat growing season	**Bosnia and Herezegovina**			**Federation of B & H**			**Tuzla Canton**		
	ArLG	**Winter wheat**		**ArLG**	**Winter Wheat**		**ArLG**	**Winter wheat**	
	1000 ha		**t ha^{-1}**	**1000 ha**		**t ha^{-1}**	**1000 ha**		**t ha^{-1}**
	Area	**WHA**	**Yield**	**ha**	**WHA**	**Yield**	**Area**	**WHA**	**Yield**
1999/2000	1000	104.08	3.23	425	23.66	2.6			
2000/2001	1010	105.19	2.43	412	24.88	2.2	For 2000-2004 period		
2001/2002	997	90.68	3.00	410	25.93	2.9	data not available		
2002/2003	1017	71.07	2.26	416	21.88	2.2			
2003/2004	1028	86.89	3.67	416	20.18	3.3			
2004/2005	1025	81.24	3.06	411	21.33	3.0	82.36	3.46	3.3
2005/2006	1027	73.35	3.17	409	20.02	3.3	80.09	3.62	4.0
2006/2007	1022	73.97	3.48	400	19.62	3.7	82.98	3.86	4.2
2007/2008	1008	64.39	3.74	400	19.60	3.8	79.13	3.28	4.3
2008/2009	997	67.77	3.78	391	19.01	3.9	79.81	3.59	4.6
2009/2010	1004	54.62	2.66	398	17.28	2.9	80.86	3.32	3.0
2010/2011	1005	58.40	3.60	390	17.84	3.8	84.85	3.14	4.3
2011/2012	1006	60.71	3.71	396	18.87	3.6	84.35	3.26	3.7
2012/2013	1008	67.63	3.92	402	19.23	4.0	87.24	3.57	4.7
2013/2014	1004	60.10*	2.90*	396	18.25	3.1	86.13	3.44	2.4
Average	**1010**	**74.67**	**3.24**	**405**	**20.50**	**3.2**	**82.78**	**3.45**	**3.8**
Territory	51 197 km^2			26 110 km^2			2 649 km^2		

** Sources: [1,9-12]*

The impact of weather characteristics on yield of wheat were estimated also in other studies. As in Croatia less permeable soils are dominant, particularly in the middle and western part of Pannonian basin, excessive precipitation mainly in the autumn/winter period connected with the lower yields of wheat, while drought limits yields in eastern Hungary [5].

Jolankai and Birkas [23] tested precipitation impacts on yield of wheat in long term field trials (1996-2010) on chernozem in Hungary. Annual yield variations were from 2.88 to 7.82 t ha^{-1}. Low yields of wheat in five growing seasons were connected with either low (average 398 mm) or excessive (average 842 mm) annual precipitation. In five growing seasons yields were above 6.0 t ha^{-1} (average 6.75 t ha^{-1}) and annual precipitation were more balanced in range from 463 to 725 mm (average 603 mm).

By corresponding soil management, for example P fertilization (24-26) it is possible to alleviate detrimental effects of unfavorable weather conditions on field crops yields in B&H.

Although it is evident that yields of wheat (Table 2) and weather conditions (Table 3) in B&H are very different among years, by statistical analysis were found with a minor connection of precipitation and temperature with yields. Significant negative correlations were found with an only in the level of Tuzla Canton between yields and monthly values of precipitation in April (-0.88**), May (-0.70**) and total precipitation (-0.73**). Also, significant positive correlations were found between monthly values of temperature in April (0.76**), May (0.62*) and yields. By using 3-month values of data, significant correlations of same directions as in case of monthly data were found

between weather conditions in April-June (precipitation: -0.85**; temperature: 0.65) period (Table 4).

Acid soils are a significant limitations to crop production worldwide [27] and in B&H [28,29]. Current climate changes and variability have significant impacts on soil properties including inclination to soil acidification [30]. Deviation of weather from usual is additional detrimental factor of crops yield on less fertile soils.

Jovic et al. [31] applied increased rates of P fertilizer on calcaric alluvial soil of Posavian Canton of FB&H and found a significantly increased maize yield for 8% compared to standard fertilization and for 53% compared to unfertilized treatment. Also, as affected by P fertilization yields of wheat were significantly increased for 13% and 15%, and soybeans for 20% (Table 5).

Ameliorative phosphorus fertilization up to 1750 P_2O_5 kg ha^{-1} resulted mainly by a significant yield increase [32] in level 17% (4-year means 2005-2008: 4.30 and 5.02 t ha^{-1}, for control and ameliorative P-fertilized treatments, respectively).

Komljenovic et al. [33] reported an impact of liming (10 t hydrated lime ha^{-1}) and P fertilization (up to 1500 kg P_2O_5 ha^{-1}). Yields of maize were significantly increased by 31% on average (liming effect) and 8% (P effect). Liming was particularly useful under drought stress conditions in 2011 and 2012 growing seasons because yields were increased up to 47% and 25%, respectively, while the highest effect of P fertilization were found in 2011 because yield was increased up to 19%.

Table 3. Meteorological data

Wheat growing season	**Tuzla Weather Bureau: precipitation (mm) and mean air-temperatures (°C)***										
		The growing season of wheat (LTM: long-term mean 1961-1990)									**Sum**
		Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**April**	**May**	**June**	**Mean**
1999/2000	mm	39	143	184	37	35	62	59	52	47	658
	℃	10.9	3.7	1.0	-2.5	2.8	6.1	13.7	16.7	19.7	8.0
2000/2001	mm	45	45	66	103	54	61	93	67	338	872
	℃	13.4	10.4	3.9	3.8	3.6	10.9	9.9	16.3	16.7	9.9
2001/2002	mm	13	116	36	29	38	49	122	175	80	658
	℃	13.3	3.1	-3.0	-0.7	6.1	8.4	10.2	16.5	19.8	8.2
2002/2003	mm	113	59	54	59	35	13	34	72	47	486
	℃	11.5	10.2	1.3	-0.8	-2.6	5.6	10.2	18.0	22.3	8.4
2003/2004	mm	178	30	63	78	79	27	163	104	98	820
	℃	9.1	8.0	0.9	-1.0	2.6	5.9	11.3	13.4	18.2	7.6
2004/2005	mm	79	95	49	51	90	79	70	73	194	780
	℃	13.7	4.9	2.2	-0.4	-2.8	3.6	10.6	15.4	17.6	7.2
2005/2006	mm	21	31	119	39	46	99	97	74	134	*660*
	℃	11.1	5.1	1.1	-1.8	1.0	5.0	11.6	14.9	18.2	*7.4*
2006/2007	mm	40	45	43	65	52	77	18	89	58	*487*
	℃	12.6	7.0	3.4	5.4	6.4	8.7	12.2	16.7	21.4	*10.4*
2007/2008	mm	114	88	54	30	14	96	54	100	113	*663*
	℃	9.5	3.2	-0.3	2.7	4.7	7.0	11.8	16.4	20.1	*8.3*
2008/2009	mm	47	79	63	62	44	99	32	56	160	*642*
	℃	12.2	7.8	4.1	-1.3	1.7	6.2	13.0	17.3	18.5	*8.8*
2009/2010	mm	136	72	136	86	74	55	102	177	257	*1095*
	℃	10.3	8.2	3.3	-0.3	1.8	6.3	11.2	15.1	19.0	*8.3*
2010/2011	mm	65	57	68	32	37	14	29	86	74	*462*
	℃	8.7	9.6	1.3	0.9	0.9	6.1	12.1	14.8	19.2	*8.2*
2011/2012	mm	45	15	61	75	79	11	92	137	56	*571*
	℃	9.6	2.8	3.0	0.6	-4.2	8.4	11.5	14.8	21.4	*7.5*
2012/2013	mm	72	34	89	82	80	80	31	168	74	*636*
	℃	12.3	9.5	0.9	2.7	2.5	5.7	12.8	15.7	18.6	*9.0*
2013/2014	mm	58	96	2	29	39	72	187	339	64	*886*
	℃	12.9	7.6	1.4	5.3	6.7	8.6	11.5	14.5	18.5	*9.7*
Average	**mm**	**71**	**67**	**72**	**57**	**53**	**60**	**80**	**118**	**120**	***692***
2000-2014	**°C**	***10.6***	***6.7***	***1.6***	***0.8***	***1.9***	***6.3***	***11.6***	***15.8***	***19.3***	***8.3***
LTM	mm	56	71	72	59	55	61	76	92	111	653
1961-1990	℃	10.6	5.6	0.9	-0.8	1.7	5.7	10.4	14.8	17 .7	7.4
LTM	mm	110	79	80	53	49	70	89	110	100	740
1925-1940	℃	10.7	6.9	0.2	-0.8	0.3	5.2	10.4	14.8	18 .5	7.4

** Sources: [13-15]*

Table 4. Correlation coefficients between yields of wheat and weather conditions

Correlation coefficients (r) between wheat yield in Bosnia and Herzegovina (B&H), Federation B&H (Fed.), Tuzla Canton (TC) and weather conditions in Tuzla									
	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**
Precipitation (monthly values) : Yield									
B&H	-0.01	-0.22	-0.01	-0.12	-0.11	0.19	-0.24	-0.09	-0.41
Fed.	-0.03	-0.31	-0.17	-0.14	0.08	0.28	-0.28	0.07	-0.34
TC	-0.24	-0.42	0.22	0.12	-0.20	0-17	-0.88**	-0.70**	-0.26
Temperature (monthly values) : Yield									
B&H	-0.40	-0.29	-0.06	0.02	0.05	-0.19	0.58	-0.27	0.03
Fed.	-0.33	-0.15	0.02	0.20	0.10	-0.17	0.58	-0.26	0.06
TC	-0.23	0.11	-0.09	-0.16	-0.03	-0.17	0.76**	0.62*	0.20
Precipitation (3-month and growing season values) : Yield									
B&H	Oct.- Dec.	- 0.12	Jan.- March	0.10	April -June	- 0.41	Oct-June	-0.37	
Fed.		- 0.32		0.14		- 0.28		-0.34	
TC		- 0.18		0.05		- 0.85**		-0.73**	
Temperature (3-month and growing season values) : Yield									
B&H	Oct.- Dec.	- 0.38	Jan.- March	- 0.02	April -June	0.18	Oct-June	- 0.15	
Fed.		- 0.22		0.08		0.17		- 0.01	
TC		- 0.08		- 0.12		0.65*		0.03	

Table 5. Impact of P fertilization on grain yield and ears density in square meter area

Impacts of phosphorus fertilization (March 12, 2011) of winter wheat and soybean status*						
P_2O_5 ** kg ha^{-1}	**Soybean**	**Winter wheat*** **				
	2011		**2011/2012**		**2012/2013**	
	t ha^{-1}	**PD in m^2**	**t ha^{-1}**	**ED in m^2**	**t ha^{-1}**	**ED in m^2**
75	2.11	37.3	6.21	756	6.44	450
225	2.44	36.3	6.90	795	7.05	499
375	2.53	36.7	6.81	831	7.06	522
525	2.36	35.7	6.94	840	7.41	563
975	2.37	36.0	7.04	952	7.32	570
Average	2.36	36.4	6.78	835	7.06	521
$LSD_{0.05}$	0.24	ns	0.54	116	0.51	39

** grain yields (t ha^{-1}), plant density (PD) and ears density (ED) per m^2 of area*
*** in the next years only standard fertilization of the experiment*
**** The main unfavorable features of the growing seasons (wheat):*
The 2011/2012: drought during early growth, dry and and very cold February.
The 2012/2013: oversupplies of precipitation in winter period and the lower precipitation in the last three months, particularly in June
Sources: [24-26]

Markovic et al. [34] applied up to 20 t dolomite ha^{-1} and yield of maize significantly increased close to 50%. Under drought stress conditions in 2007, by liming yields were increased up to 47%.

In neighboring Croatia there are similar limitations of main field crops yield as in B&H. For this reason, liming and ameliorative P fertilization mainly resulted in considerable increases of yield [35-40].

4. CONCLUSIONS

Variation in wheat yields in B&H (2.26 to 3.92 t ha^{-1}) among years were found mainly as result of different weather conditions. Average temperature in the last 15-year period in Tuzla (October-June) was 8.3 ℃ or 0.9℃ higher than 1961-1990 average, and precipitation showed increased yearly variability. Precipitation around the 30-year average and balanced monthly distribution as well temperature regime without excessive cold or warm periods characterized favorable growing seasons, whereas weather deviations in terms of drought or excessive precipitation in combination with high temperatures resulted in considerably lower yields of wheat. However, by performing simple correlation analysis it was found that only minor connection of precipitation and temperature with yields. Significant negative correlations were found in TC between yields and monthly values of precipitation in April, May and total precipitation. Also, significant positive correlations were found between April and May temperature and yields. Alleviation of detrimental

effects of weather characteristics is possible by improvement of soil by reclamation and liming, adequate fertilization, especially with phosphorus.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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