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Review paper

Weather Characteristics and Yield of Wheat in Bosnia and Herzegovina with emphasis on Climatic Change and Tuzla Canton

ABSTRACT Aim of this study was testing 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 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 Bosnia and Herzegovina (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}). Yield differences are mainly due to weather variability. Because of global warming, average temperature in Tuzla was 8.3°C in the last 15 years or 1.1°C higher than the 1961-1990 and 1925-1940 averages. Precipitation similar to the 30-year average (663 mm, 642 mm and 636 mm in 2007/2008, 2008/2009 and 2012/2013, respectively) together with balanced monthly distribution characterized the three seasons favorable for growing wheat. In these years there were no excessive cold or warm periods. Under these conditions, wheat yields were considerably higher (3.7 , 3.8 and 3.9 t ha^{-1} , respectively) than in three 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 resulted in considerably lower yields in unfavorable years. Tuzla Canton had about 5% of the national wheat harvested area, whereas yields were somewhat higher compared to the country average. By adequate soil and crop management, for exemple, mineral fertilization, and liming, is possible to alleviate negative effects of weather conditions on yields.

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Key words: Bosnia and Herzegovina, Climatic change, Grain yield, Precipitation, Temperature, Winter wheat

1. INTRODUCTION

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Global warming and more frequency of the extremely weather conditions is oft connected with climatic changes. Annual global temperatures have increased by about 0.4°C 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% variations of global average yields for the world's most widely grown crops are 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, average wheat harvested area in B&H was 74,673 ha with average grain yield of 3.24 t ha^{-1} and yearly variation from 2.26 to 3.92 t ha^{-1} [3]. Weather

characteristics during the growing seasons are the main reason for variation in annual yields in the period considered. In neighboring Croatia and nearby Hungary low wheat yields are associated mainly with either excessive or low precipitation. Under environmental conditions of the Eastern Croatia, there are indications that low wheat yields are mainly in connection with precipitation excess, especially during autumn/winter period [4]. Pepo and Kovacevic [5] reported an impact of weather characteristics 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 a positive correlation between precipitation in spring and wheat yield, and negative correlation between temperature in spring and the yield of winter wheat. Beside soil and weather characteristics, many other factors influence wheat yields such as crop rotation, tillage, fertilization, crop protection, variety etc. Weather characteristics have also important role for maize growing. Majdancic et al. [6] found considerable variation in maize yield in FB&H and Tuzla Canton in the 2000-2014 period. Average grain yields of maize in FB&H was 2.99 t/ha with variation among 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-Sept. 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 °C (1.0 °C 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]. Aim of this study was testing impact of monthly precipitation and average air temperature regimes on winter wheat yields in Bosnia and Herzegovina (B&H) for the last 15-year period (2000-2014) with emphasis on its administrative parts Federation of B&H (FB&H) and Tuzla Canton with emphasis 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 wheat because of environmental stress limitations, mainly soil acidity, low nutrient supplies and unfavorable weather conditions. By adequate soil and crop managements are possible to alleviate stress induced by weather deviations.

2. MATERIAL AND METHODS

2.1. Collection of data

The FAO data base and publications of Institute for Statistics in Sarajevo [9][10][11][12] were used as the sources of wheat harvested area and yield data, while publications of Federal Hydrometeorological Institute [13] were perused for the meteorological data (monthly values of precipitation and average air temperatures) for Tuzla (44°32' N and 180 41' E). The long-term values of precipitation and temperatures (1925-1940 and 1961-1990) were shown in the other studies [4][15].

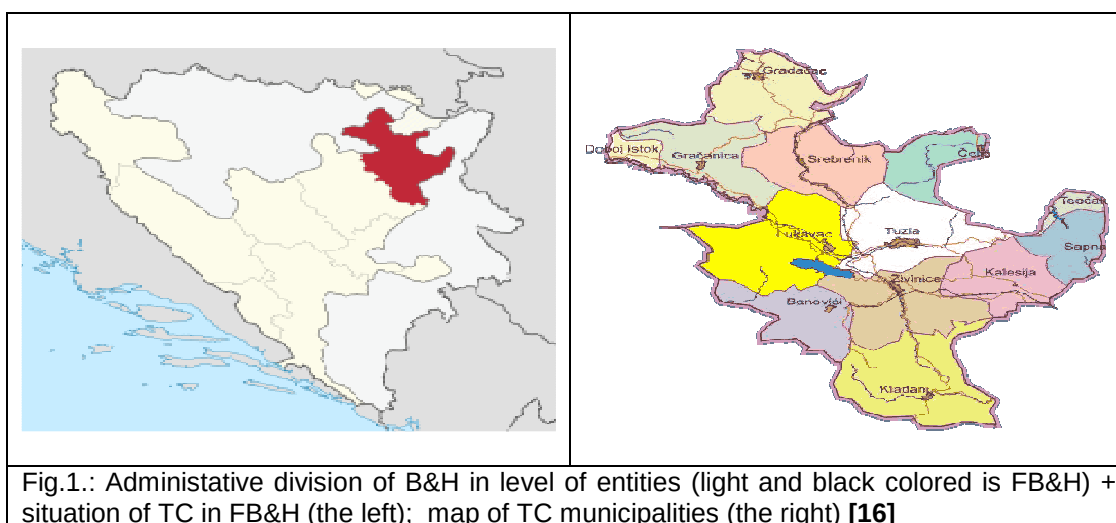
2.2. Description of the analyzed area

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 geography is mountainous, in the northwest it is moderately hilly, and the northeast is predominantly flatland. 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 (Federation of B&H and Republic of Srpska or RS) and Brcko district. The Federation of B&H consists of 10 autonomous cantons having their own governments.

FB&H covers 26,110 km². The most of this area is covered by forests, while the northern lowland area of Sava valley and the northern part of Tuzla Canton (TC) are suitable for intensive field crop production.

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Tuzla Canton (TC) is one of ten cantons of FB&H. It covers 2649 km² 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. 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 °C), whereas the warmest (19.3 °C) is July [16].



Tuzla Canton 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 1). About 48% of arable land and gardens are unfarmed in FB&H, while in TC this contribution is about 29% . [9] [10][12] .

3. RESULTS AND DISCUSSION

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 [17] [18]. 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 4.6 t ha⁻¹) (Table 1). These yield differences were mainly induced by specificity of weather characteristics during individual growing seasons. Because of global warming, average temperature in Tuzla was 8.3 °C in the last 15 years or 1.13 °C higher than the 1961-1990 average, while variability in precipitation increased among years (Table 2). Based on yields, the 2003, 2010 and 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 2003, 2010 and 2014 growing seasons were favorable for wheat growth (3.8, 3.9 and 4.5 t ha⁻¹, respectively).

Table 1. Arable land and areas covered by wheat

Arable land and gardens (ArLG) , wheat harvested area (WHA) and yields [1] [9] [10] [11] [12]									
Year	Bosnia and Herezegovina			Federation of B&H			Tuzla Canton		
	ArLG	Winter wheat		ArLG	Winter wheat		ArLG	Winter wheat	
	1000 ha	ha	t ha ⁻¹	1000	ha	t ha ⁻¹	ha	t ha ⁻¹	
	Area	WHA	Yield	ha	WHA	Yield	Area	WHA	Yield
2000	1000	104082	3.23	425	23658	2.6	For 2000-2004 period data not available		
2001	1010	105188	2.43	412	24879	2.2			
2002	997	90682	3.00	410	25927	2.9			
2003	1017	71067	2.26	416	21879	2.2			
2004	1028	86890	3.67	416	20184	3.3			
2005	1025	81239	3.06	411	21328	3.0	82364	3463	3.3
2006	1027	73348	3.17	409	20015	3.3	80086	3621	4.0
2007	1022	73968	3.48	400	19622	3.7	82978	3858	4.2
2008	1008	64392	3.74	400	19604	3.8	79128	3281	4.3
2009	997	67772	3.78	391	19011	3.9	79814	3588	4.6
2010	1004	54623	2.66	398	17282	2.9	80862	3317	3.0
2011	1005	58400	3.60	390	17836	3.8	84846	3140	4.3
2012	1006	60713	3.71	396	18866	3.6	84 347	3256	3.7
2013	1008	67630	3.92	402	19230	4.0	87 244	3567	4.7
2014	1004	60100*	2.90*	396	18250	3.1	86 134	3440	2.4
Average	1010	74673	3.24	405	20455	3.2	82780	3453	3.8
Territory	51 197 km ²			26 110 km ²			2 649 km ²		

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 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, 3.0 and 3.1 t ha⁻¹, respectively) and TC (3.0 and 3.8 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 [19] [20].

Table 2. Meteorological data [13] [14] [15]

Wheat		Tuzla Weather Bureau: precipitation (mm) and mean air-temperatures (°C)								
growing season		The growing season of wheat (LTM: long-term mean 1961-1990)								Sum Mean
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	
1999/2000	mm	39	143	184	37	35	62	59	52	47
	°C	10.9	3.7	1.0	-2.5	2.8	6.1	13.7	16.7	19.7
2000/2001	mm	45	45	66	103	54	61	93	67	338
	°C	13.4	10.4	3.9	3.8	3.6	10.9	9.9	16.3	16.7

2001/2002	mm	13	116	36	29	38	49	122	175	80	658
	°C	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
	°C	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
	°C	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
	°C	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
	°C	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
	°C	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
	°C	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
	°C	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
	°C	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
	°C	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
	°C	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
	°C	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
	°C	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	°C	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	°C	10.7	6.9	0.2	-0.8	0.3	5.2	10.4	14.8	18.5	7.4

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, 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 3.92 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 °C and June for 0.8 °C, while December, February and March were warmer for 0.7 °C, 1.4 °C, and 0.5 °C, respectively. However, average data of 2000-2014 period showed trend of warming because average temperature in October-June period were higher for 0.9 °C compared to 1925-1940 and 1961-1990 periods. The

mean air-temperature in the coldest January in 2000-2014 period was higher for 1.6 °C (Table 2).

Impact of weather characteristics on yield of wheat were tested also in other studies [21]. As in Croatia are dominant less permeable soils, particularly in the middle and western part of Pannonian basin, excessive precipitation mainly in autumn/winter period are in connection with the lower yields of wheat, while drought limits yields in eastern Hungary [5]. Jolankai and Birkas [21] tested precipitation impacts on yield of wheat in long term field trials (1996-2010) on chernozem in Nagygombos, 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).

Table 3. 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: grain (t ha ⁻¹), ears density (ED: ears number per m ² of area) and plant density per hectare (PD)						
P ₂ O ₅ * kg ha ⁻¹	Soybean				Winter wheat	
	2011 [22]		2011/2012 [23]		2012/2013 [24]	
	t ha ⁻¹	ED	t ha ⁻¹	PD in m ²	t ha ⁻¹	PD in m ²
75	2.11	373330	6.21	756	6.44	450
225	2.44	363330	6.90	795	7.05	499
375	2.53	366663	6.81	831	7.06	522
525	2.36	356666	6.94	840	7.41	563
975	2.37	360000	7.04	952	7.32	570
Average	2.36	363997	6.78	835	7.06	521
LSD _{0.05}	0.24	ns	0.54	116	0.51	39

* in the next years only standard fertilization of the experiment ;
crop rotation: soybean (2011) – wheat (2011/2012) – wheat (2012/2013)

Acid soils are a significant limitations to crop production worldwide [25] and in B&H [26] [27]. Current climate changes and variability have significant impacts on soil properties including inclination to soil acidification [28]. Deviation of weather from usual is additional detrimental factor of crops yield on less fertile soils. By correspondingly soil management, is possible to alleviate detrimental effects of unfavorable weather characteristics on wheat and other field crops yields in B&H. Jovic et al. [29] applied increased rates of P fertilizer on calcaric alluvial soil of Posavian Canton and found increase maize yield for 8% compared to standard fertilization and for 53% compared to unfertilized treatment. Also, as affected by fertilization yields of wheat were increased for 13% and 15%, and soybeans for 20% (Table 3). Ameliorative phosphorus fertilization up to 1750 P₂O₅ kg ha⁻¹ resulted mainly by considerable yield increase [30] 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. [31] reported an impact of liming (10 t hydrated lime ha⁻¹) and P fertilization (up to 1500 kg P₂O₅ ha⁻¹). Yields of maize were increased by 31% on average (liming effect) and 8% (P effect). Markovic et al. [32] applied up to 20 t dolomite ha⁻¹ and yield of maize increased close to 50%. In neighboring Croatia are similar limitations of main field crops yield as in B&H. For this reason, liming and ameliorative P fertilization mainly resulted by considerable increases of yield [33].[34][35][36] [37] [38].

4. CONCLUSIONS

Yields of wheat in B&H are low mainly because of unfavorable soil physical and chemical characteristics, little hydro- and agromelioration as well as inadequate soil and crop management practice. Variation in wheat yields (2.26 to 3.92 t ha⁻¹) among years were found

as result of different weather characteristics. Because of global warming, average temperature in the last 15-year period in Tuzla was 8.3 °C or (1.1 °C higher than 1961-1990 average), and precipitation showed increased yearly variability. Precipitation around 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. 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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