Impact of weather on the spring crops yield in Croatia with emphasis on climatic change and the 2014 growing season

V. Kovacevic – J. Sostaric
University J. J. Strossmayer in Osijek, Faculty of Agriculture, Osijek, Croatia

SUMMARY

Main field crops in Croatia are maize, soybean, sunflower and sugar beet. By these crops are covered (status 2014) close to 50% (385 234 ha) of utilized arable land. Global warming, have often adverse influence on field crop yields. Aim of this study was testing precipitation and temperature regimes on spring crops yield in Croatia in 15-year period (1999–2013) and elaboration of the 2014 growing season with aspect of climatic change. Four growing seasons (2000, 2003, 2007 and 2012) were less favorable for maize because annual yield was bellow 5 t ha⁻¹ (average 4.38 t ha⁻¹), while in four more favorable years (2005, 2008, 2009 and 2010) annual yield was above 6.8 t ha⁻¹ (average 7.32 t ha⁻¹). Average precipitation and temperature for the April-September period in Osijek were 226 mm and 496 mm, 19.6 °C and 18.6 °C, for less and more favorable years, respectively. Yields of soybeans and sugar beet have mainly similar trend as maize yields in function of weather conditions, while sunflower is more susceptible to extremely moist growing seasons (for example, 2001 and 2005: 650 mm and 697 mm precipitation and very low yields in level 1.7 and 1.6 t ha⁻¹, respectively). On the other side, under drought conditions of 2003, 2007 and 2012, yields of sunflower were above average in range from 2.5 to 2.7 t ha⁻¹), while at same period yields of maize, soybean and sugar beet were drastically reduced.

Average precipitation in the April-September period of 2014 for eight selected sites of Croatia was 756 mm or for 68% higher in comparison with the long-term average 1961–1990 with variation among the sites from 520 mm in Osijek to 910 mm in Varazdin. On the other side, average air-temperature in 2014 was 17.8 °C or for 0.7 °C higher with variations among the sites from 17.2 °C in Daruvar and Varazdin to 18.2 °C in Osijek and 18.3 °C in Gradiste. Under these favorable weather conditions, annual yields of maize (8.1 t ha⁻¹), soybeans (2.8 t ha⁻¹), sunflower (2.9 t ha⁻¹) and sugar beet 63.6 t ha⁻¹ were considerable higher than usual.

Keywords: maize, sunflower, soybeans, sugar beet, climatic change, precipitation, temperature, Croatia

INTRODUCTION

Main field crops in Croatia are maize, soybean, sunflower and sugar beet. By these crops were covered (status 2014) 252 567 ha (maize for grain), 28 794 ha (silage maize), 47 104 ha (soybeans), 34 869 ha (sunflower) and 21 900 ha (sugar beet) or 47.5% (385 234 ha) of utilized arable land (CBS, 2015).

Global warming and more frequency of the extremely weather conditions, mainly long drought periods and floods, is associated with climatic change. With that regards, recent status of precipitation and temperature regimes, have often adverse influence on field crop yields as well the higher amplitude their variations among years. For this reason, in many countries there is a tendency towards cereal grain yield stagnation and increased yield variability (Tim, 2000; Chi-Chung et al., 2004; Parrx et al., 2004; Vucetic, 2006, 2011; Lobel and Field, 2007; Li et al., 2011; Oseni and Masarirambi, 2011; Kovacevic et al., 2012, 2014; Liovic et al., 2012; Komljenovic et al., 2014). Some studies have indicated that 1 °C increase in global temperature will lead to reduced productivity in some cultivated plants, such as 17% in maize and soybean (Allen et al., 2003; Thomson et al., 2005). In the recent period, very high yield reduction of maize due to drought and high air-temperatures were found for the continental climate in the Pannonia zone, which includes Hungary, Croatia, Serbia, Bulgaria and Romania (Kovacevic et al., 2012, 2013).

Aim of this study was testing precipitation and temperature regimes on spring crops yield in Croatia in recent 15-year period (1999–2013) and elaboration of the 2014 growing season with aspect of climatic change.

MATERIAL AND METHODS

Description of the area

According to geographical characteristics, there are three regions in Croatia: the Mediterranean or the Adriatic region, the Mountainous region and the Pannonia region. The Pannonian region covers about 50% of Croatian territory and majority arable land and the harvested area of main field crops of the country is situated in this part of Croatia. More details about geographical position, relief, soil, climate and water resources, as well as phytogeographical characteristics, were shown in the correspondingly monography (Magas, 2013), while Kovacevic and Basic (1997) reported data with emphasis on the agroecological aspect.

The meteorological stations of eight sites situated in Pannonia region of Croatia (Figure 1) were selected for characterization of weather conditions with aspect of their degree of favorability for the spring crops growth in the 2014 growing season. This region is mainly lowland area and selected sites are elevated between 81 to 163 m above sea level (Figure 1).

Collection of data

Publications of Croatian Bureau of Statistics were used as the sources of the utilized agricultural and arable land areas, the spring crops (maize, soybeans, sunflower and sugar beet) harvested areas and yields (CBS, 2009, 2014, 2015), while publications of Meteorological and Hydrological Service Zagreb were
perused for the meteorological data (monthly values of precipitation and average air-temperatures (MHS, 1999–2013, 2014).

RESULTS AND DISCUSSION

By utilized agricultural area in Croatia were covered 1 270 044 ha (average 2004–2013) and 1 508 885 ha (status 2014) and utilized arable land participated with 68.6% and 53.7% of utilized agricultural area, respectively. Main spring crops on arable land in Croatia are maize for grain, soybean, sunflower and sugar beet (averages in 2004–2013 period: 301 046 ha, 49 121 ha, 33 081 ha and 25 644 ha, respectively). In general, considerable yield variations of the mentioned crops among years were found. With that regards, the 2014 growing season characterized by yields above 10-year averages (Table 1). As soil properties, crop management practices and used cultivars in this short period were similar, yield differences among years could be attributed mainly to specify of weather characteristics in individual growing season.

Figure 1: Position of selected meteorological stations (MS), their geographical coordinates and elevation above sea level

| MS          | Coordinates and elevation |
|-------------|---------------------------|
| Osijek (OS) | 45°33’44”N 18°42’00”E; 102 m |
| Gradiste (GR) | 45°04’20”N 18°41’40”E; 81 m |
| Slav. Brod (SB) | 45°09’36”N 18°00’36”E; 90 m |
| Daruvar (DA) | 45°35’34”N 17°13’25”E; 163 m |
| Bjelovar (BJ) | 45°54’36”N 16°50’24”E; 111 m |
| Sisak (SI) | 45°28’48”N 16°21’36”E; 102 m |
| Zagreb (ZG) | 45°48’43”N 15°58’52”E; 125 m |
| Varazdin (VZ) | 46°18’15”N 16°20’16”E; 154 m |

From OS to VZ: air-distance approximately 200 km

The harvested areas and yields of main spring field crops in Croatia

| The utilized area | The harvested area | Yield (t ha⁻¹) |
|------------------|-------------------|---------------|
| Agric. area | Arable land | Maize Grain | Soybean Silage | Sunflower | Sugar-beet | Maize Grain | Soybean Silage | Sunflower | Sugar-beet |
| Republic of Croatia – 10-year averages (2004–2013) | | 871 321 | 26 547 | 49 121 | 33 081 | 25 644 | 4.35 | 31.6 | 2.45 | 2.60 | 49.6 |
| Annual yield variation in 2004–2013 period: Minimum | | 301 046 | 25.644 | | | | 4.40 | 25.8 | 1.80 | 1.60 | 39.1 |
| Maximum | 8.10 | 35.3 | 3.00 | 3.20 | 57.7 |

Republic of Croatia – the 2014 growing season

| The utilized area | The harvested area | Yield (t ha⁻¹) |
|------------------|-------------------|---------------|
| 1 508 885 | 811 067 | 252 567 | 28 794 | 47 104 | 34 869 | 21 900 | 8.10 | 35.3 | 3.00 | 3.20 | 63.60 |

Source: CBS (2009, 2014, 2015)

Variation of maize yields in Croatia during 15-year period 1999–2013 could be used as typical example of impact precipitation and temperature regimes on maize yields. Annual yield variation in this period was from 4.1 t ha⁻¹ in 2000 to 8.0 t ha⁻¹ in 2008. Four growing seasons were less favorable for maize (2000, 2003, 2007 and 2012) because annual yield was below 5 t ha⁻¹ (average 4.38 t ha⁻¹), while in four more favorable years (2005, 2008, 2009 and 2010) annual yield was above 6.8 t ha⁻¹ (average 7.32 t ha⁻¹). Average precipitation and temperature for the April-September period in Osijek were 226 mm and 19.6 °C and 18.6 °C, for less and more favorable years, respectively (Table 2).

Low yields of maize in unfavorable years were in close connection with drought in June and August (total 15 mm precipitation) and high air-temperature (23.7 °C) in August of 2000, high temperatures in June (24.3 °C) and August (23.6 °C) accompanied with moderate precipitation in 2003, drought and high temperature in June and July of 2007 (58 mm precipitation and temperature 25.1 °C) in 2007, while extremely drought and high temperature in August (4 mm and 24.8 °C) were responsible for low yield of maize in 2012 (Table 2). Specified of unfavorable the 2012 growing season (Meteorological Station Osijek) were the highest average air-temperature in level 20.0 °C for April-September period (Table 3) and absolute maximum in August 40.3 °C (Kovacevic et al., 2013). The highest annual yield of maize in Croatia for 1999–2013 periods were recorded in 2008. This growing season was characterized by adequate (404 mm) and good distributed monthly precipitation, as well as the lower temperature (average 18.1 °C) without considerable oscillations (21.5 °C in June, 21.8 °C in July and 21.8 °C in August).

Kovacevic et al. (1994) reported survey of maize yield and precipitation regime for 1960–1990 period in Slavonia and Barannya which approximately covers the eastern Croatia region. In this study was found similar impact of weather conditions on maize yield as in our study. In this period, the average harvested area of maize in Croatia 509 068 ha and it was relative stable among the years, while yields had the increasing trend.
as follows: 2.90 t ha⁻¹, 3.85 t ha⁻¹ and 4.68 t ha⁻¹, for decade periods 1960-ies, 1970-ies and 1980-ies, respectively.

Yields of soybeans and sugar beet have mainly similar trend as maize yields in function of weather conditions impacts, while sunflower is more susceptible to extremely high air-temperatures (Lobel and Field, 2007; Vucetic, 2011). Our data are in accordance with these observations. Also, we confirmed of climate change by global warming (Lobel and Field, 2007; Vucetic, 2011).

The 2014 growing was very favorable for the majority spring crops because of adequate and good monthly distributed precipitation and avoidance of extremely high air-temperatures (Table 3).

Average precipitation in the April-September period of 2014 for eight selected sites of Croatia was 756 mm average (LTA) 1961–1990 with variation among the sites from 520 mm in the eastern situated Osijek to 910 mm in western situated Varazdin. On the other side, average air-temperature in 2014 was 17.8 °C or for 0.7 °C higher with variations among the sites from 17.2 °C in Daruvar and Varazdin to 18.2 °C in Osijek and 18.3 °C in Gradiste (Table 3). In general, climate trend in the Pannonia region is characterized by increase of annual precipitation and decrease of temperature in direction from east toward west (Rastija et al., 2012; Magas, 2013; Kovacevic and Rastija, 2014). Our data are in accordance with these observations. Also, we confirmed of climate change by global warming (Lobel and Field, 2007; Vucetic, 2011).

### Table 2. Yields of main spring crops in Croatia and weather conditions in Osijek

| Year                  | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|-----------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Yields of main spring crops in Croatia (t ha⁻¹) |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Maize                 | 5.6  | 4.1  | 5.7  | 6.4  | 4.2  | 6.3  | 6.9  | 6.5  | 4.9  | 8.0  | 7.4  | 7.0  | 5.7  | 4.3  | 6.5  |
| Soybean               | 2.5  | 1.4  | 2.2  | 2.7  | 1.7  | 2.7  | 2.5  | 2.8  | 1.9  | 3.0  | 2.6  | 2.7  | 2.5  | 1.8  | 2.4  |
| Sunflower             | 2.1  | 2.1  | 1.7  | 2.3  | 2.5  | 2.4  | 1.6  | 2.3  | 2.6  | 3.1  | 3.0  | 2.3  | 2.8  | 2.7  | 3.2  |
| Sugarbeet             | 40.0 | 23.0 | 40.6 | 47.1 | 24.8 | 47.6 | 45.5 | 48.9 | 46.1 | 57.2 | 52.8 | 52.4 | 53.8 | 39.1 | 51.9 |

### Table 3. Weather conditions in eight selected sites of Pannonian region in Croatia (MHS, 2014)

| Month       | April | May   | June  | July  | August | September |
|-------------|-------|-------|-------|-------|--------|-----------|
| Precipitation (mm) | 505   | 155   | 650   | 461   | 227    | 471       |
| Mean air-temperature in Osijek (°C) | 17.7  | 17.4  | 17.0  | 17.4  | 16.1   | 15.8      |
| Source: CBS (2005, 2009, 2014), MHS (1999–2013) |      |      |      |      |       |           |

Source: MHS (2014), Note: * Osijek (OS), Gradiste (GR), Slavonski Brod (SB), Daruvar (DA), Bjelovar (BJ), Sisak (SI), Zagreb-Maksimir (ZG), Varazdin (VZ)

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In general, low yields of maize are in close connection with drought accompanied with high temperatures, particularly in two summer months July and August (Kovacevic et al., 2012; Stojic et al., 2012; Kovacevic et al., 2013; Videnovic et al., 2013; Majdancic et al., 2016). Weather conditions have similar role as in maize for their impact on yields of the other spring crops (Liovic et al., 2012; Vrataric and Sudaric, 2008; Kovacevic and Kausic, 2014). Also, yields of winter crops are under considerable impacts of weather conditions, for example wheat (Marijanovic et al., 2010; Pepo and Kovacevic, 2011; Sostaric et al., 2014; Majdancic et al., 2016) and other winter crops (Ilijic et al., 2014).

Vucetic (2011) studied the impact of present climate on maize yield using DSSAT 4.0 with meteorological data from the Zagreb–Maksimir station covering the period 1949–2004. The location is representative of the continental climate in central Croatia. The linear trends of model outputs and the non-parametric Mann–Kendall test indicate that the beginning of silking has advanced significantly by 1.4 days/decade since the mid-1990s and maturity by 4.5 days/decade. It also shows a decrease in biomass by 122 kg ha\(^{-1}\) and in maize yield by 216 kg ha\(^{-1}\) in 10 years.

Kovacevic et al. (2012) analyzed the data of the two-decade period between 1990–2012 of precipitation and temperature, particularly precipitation and temperature, with aspect of climatic in Serbia with emphasis on the Belgrade region. Annual air temperatures in the investigated period increased not only at the annual level, but also in the vegetative period of winter wheat and particularly maize. The temperature increase is particularly dangerous in the vegetative period of maize during June, July and August by almost 2\(^\circ\)C. Precipitations at a monthly level of the vegetative period or a total per year do not provide such a picture. Besides the lack in July, precipitations are somewhat higher than the reference 30-year period 1971–2000.

Irrigation in critical stages under water deficit conditions is very useful management practice for elimination negative effects of drought on maize yield. For example, in stationary field experiment on eutric cambisol of Agricultural Institute Osijek, maize yield in less favorable growing seasons (2000, 2007 and 2012) were increased compared to non-irrigated plot for 24.0%, 31.5% and 47.4%, respectively (Table 4).

Also, by correspondingly soil management, for example liming and fertilization, is possible to alleviate negative effects of drought and high temperature on field crops yield (Kovacevic and Basic, 1997; Sostaric and Josipovic, 2006; Antunovic, 2008; Markovic et al., 2008, 2013; Komljenovic et al., 2010, 2015; Andric et al., 2012; Stojic et al., 2012; Kovacevic and Loncaric, 2014; Kovacevic et al., 2015).

### Table 4.

| Irrigation | Response of maize to irrigation (the experimental field of Agricultural Institute Osijek) |
|------------|-------------------------------------------------------------------------------------|
|            | Grain yield of maize (t ha\(^{-1}\))** | ** 2000 | 2002 | 2004 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | Mean |
| Control (non-irrigated) | 10.18 | 11.87 | 10.91 | 8.29 | 8.61 | 8.37 | 9.89 | 8.40 | 6.81 | 6.73 | 9.07 |
| 80–100% FWC** | 12.62 | 12.44 | 11.97 | 10.32 | 11.32 | 9.65 | 12.20 | 8.56 | 9.23 | 9.92 | 10.82 |
| LSD\(_{0.05}\) | 0.65 | 0.13 | 0.49 | 0.27 | 0.44 | 0.30 | 0.22 | ns | 0.33 | 0.32 |
| Yield increase (%) | 24.00 | 4.80 | 9.70 | 24.50 | 31.50 | 15.30 | 23.40 | 0 | 35.50 | 47.40 |

Source: Josipovic (2013). Note: * maintenance of soil moisture by irrigation in range 80–100% field water capacity (FWC), ** 2000–2004: average of 3 fertilization + 4 replicates (12 individual results for each treatment), ** 2005–2012: average of 3 fertilization + 4 hybrids + 4 replicates (36 individual results for each treatment).

### CONCLUSIONS

Maize, soybeans, sunflower and sugar beet are main field crops on arable land in Croatia. Weather conditions, particularly precipitation and temperature regimes, have considerable impact on yield of these four crops. With that regard, global warming and more frequency of the extremely weather conditions have often adverse influence on field crop yields as well the higher amplitude their variations among years. For example, in 15-year period (1999–2013) variation of annual yields were in ranges (t ha\(^{-1}\)) from 4.1 to 8.0 (maize), from 1.4 to 3.0 (soybeans), from 1.6 to 3.2 (sunflower and from 23.0 to 57.7 (sugar beet). In general, the lower precipitation in combination with the higher temperatures are associated with the lower yields of maize, soybeans and sugar beet, while sunflower yields were low in very moist years. The growing season 2014 was mainly very favorable for spring crops because of adequate and good distributed precipitation and moderate temperatures. Under these favorable weather conditions, annual yields of maize (8.1 t ha\(^{-1}\)), soybeans (2.8 t ha\(^{-1}\)), sunflower (2.9 t ha\(^{-1}\)) and sugar beet 63.6 t ha\(^{-1}\)) were considerable higher than usual.

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