**Drought as a limiting factor of maize yields in Croatia and Serbia**

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The first year of study, Master study Plant growing – plant production

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**Abstract:** Maize is main field crop on the arable lands in Croatia and Serbia. The harvested areas of maize in 2003-2012 were in Croatia 313918 ha and in Serbia 1216786 ha or about third part of total arable lands. The annual yield variations among the years were from 3.86 to 8.00 t ha-1 in Croatia and from 3.2 to 6.7 t ha-1 in Serbia. The general statement that the lower maize yields is in connection with the lower precipitation and the higher air-temperatures, especially in July and August. The highest yields of maize were in 2010 both in Vukovar-Syrmium County and Vojvodina (8.00 and 6.7 t ha-1, respectively) and they are mainly result of adequate precipitation in July and August (143 mm in Osijek and 150 mm in Sremska Mitrovica) and the lower temperatures (22.4oC and 22.7oC, respectively). Also, the lowest yields in 2012 (3.80 t ha-1 and 3,2 t ha-1, respectively) were associated with drought (52 mm and 40 mm, respectively) and high air-temperatures (24.5 and 24.7oC, respectively). Estimated yields of maize in 2012 for Croatia 4.2 t ha-1 and Serbia 3.12 t ha-1 are lower in comparison with the yields in the favorable 2010 growing season for about 40%.

**Key words:** maize, yield, weather characteristics, precipitation, air-temperature

**Introduction**

Maize (*Zea mays* L.) is main field crop on the arable lands in Croatia and Serbia. According the statistical data (SYBcro, 2011; SYBserb, 2011) the harvested areas and yield of maize (5-year averages: 2006-2010) were in Croatia 298697 ha and 6.76 t ha-1 and in Serbia 1216786 ha and 4.86 t ha-1. About third part of total arable lands of individual country were covered by maize. Considerable annual yield variations of maize in this short period were 4.9 to 8.0 t ha-1 (Croatia) and 3.2 to 5.9 t ha-1 (Serbia).

The weather characteristics, especially precipitation quantities and their distributions as well as air-temperature regime, are main reason of yield variations of maize among years. In that respect, the lower air-temperatures and the higher precipitation in two summer months July and August compared to usual for the correspondingly area are mainly in connection with the higher yields of maize (Shaw 1988; Maklenovic et al., 2009; Kovacevic et al., 2009, 2012; Rastija et al., 2012). Aim of this study was testing weather characteristics and maize yields in Croatia (HR) and Serbia (SRB) with emphasis on Vukovar-Syrmium County (HR) and Vojvodina province (SRB) in the decade period from 2003 to 2012.

**Material and methods**

***Description of the areas***

Republic of Croatia covers 56538 km2 area of territory. The utilized agricultural area was 1326083 ha and arable land participated with 892221 ha or 67.3% of the utilized agricultural area of the country (status 2011 – SYBcro, 2012). According the same source, main field crops in Croatia are maize (for grain 305130 ha and silage maize 33041 ha), wheat (149797 ha), soybean 58896 ha), barley (48318 ha), sunflower (30041 ha) and sugar beet (21723 ha). Vukovar-Syrmium County (VuSC) covers area of 2441 km2 or 4.3 % of the state territory. It is situated in the SE edge of Pannonian region.

Republic of Serbia covers 77474 km2 area of territory located at the crossroads of Central and Southern Europe covering the southern part of the Pannonian Plain and the central Balkan. Agricultural area of the country has been 5056000 ha and arable land participating with 3294000 ha or 65.1% of agricultural area of the country (status 2011 – SYBsrb, 2012). Main field crops in Serbia (status 2011) are maize (for grain 1258437 ha and silage maize 30157 ha), wheat (493006 ha), sunflower (174270 ha) soybean 165253 ha) and sugar beet (55627 ha).The Vojvodina province is mainly lowland area situated in the southern part of the Pannonian Plain covers 21506 km2 or 28% of the state territory. However, contribution of Vojvodina province in arable land and wheat harvested areas in Serbia is about 50%, maize about 60%, while majority (above 90%) of sunflower, soybean and sugar beet harvested areas is situated in Vojvodina.

***Collection of the data***

The data of State Bureau for Statistics (SBS) and State Hydrometerological Institute in Zagreb and Belgrade were used as source majority of maize yield and weather data. Three weather bureaus both in Croatia and in Serbia (Table 1) were selected for comment of the weather characteristics.

Table 1. The geographic coordinates of the selected towns

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Geographic latitude (Lat.) and longitude (Long.) of selected towns | | | | | | |
|  | Croatia | | | Serbia | | |
|  | Osijek (OS) | Bjelovar  (BJ) | Zagreb  (ZG) | Kikinda  (KI) | Sr. Mitrovica  (SM) | Ni  (NI) |
| Lat. | 45o33΄ N | 45o52΄ N | 45o15΄ N | 45o51΄ N | 45o06΄ N | 43o19΄ N |
| Long. | 18o41΄ E | 16o50΄ E | 15o13΄ E | 20o28΄ E | 19o33΄ E | 21o54΄ E |

**Results and discussion**

The harvested areas of maize in Croatia and Serbia in the 2003-2012 period were 313918 ha and 677090 ha and average yields were 6.09 and 5.33 t ha-1, respectively. The annual yield variations among the years in the country level were in range from 3.86 to 8.00 t/ha in Croatia and from 3.2 to 6.7 t ha-1 in Serbia. Both in the VuSC and Vojvodina province, maize yields were the higher in comparison with the state means, mainly as result of more favorable soil characteristics (Table 2).

Table 2. Areas and yields of maize in the 2003-2012 decade period (SYBcro, 2012; SYBserb, 2012)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | Maize harvested areas (ha) and yields (t ha-1) in Croatia and Serbia, as well in the Vukovar-Syrmium County (VuSC) and Vojvodina province | | | | | | | |
|  | Croatia | | | | Serbia | | | |
|  | Country | | VuSC\*\* | | Country | | Vojvodina | |
|  | ha | t ha-1 | ha | t ha-1 | ha | t ha-1 | ha | t ha-1 |
| 2003 | 405947 | 3.86 | 44646 | 5.15 | 1199871 | 3.18 | 621 612 | 3.4 |
| 2004 | 306667 | 6.30 | data no exist | | 1199921 | 5.50 | 633 498 | 5.9 |
| 2005 | 318891 | 6.92 | 32670 | 8.38 | 1220174 | 5.78 | 649465 | 6.5 |
| 2006 | 296251 | 6.53 | 26990 | 7.44 | 1169976 | 5.08 | 618865 | 5.9 |
| 2007 | 288549 | 4.94 | 30262 | 5.39 | 1201832 | 3.20 | 660201 | 4.1 |
| 2008 | 314062 | 8.00 | 30595 | 7.50 | 1254200 | 4.90 | 731381 | 5.6 |
| 2009 | 296910 | 7.40 | 24908 | 7.50 | 1197802 | 5.30 | 674584 | 5.9 |
| 2010 | 296768 | 7.00 | 27205 | 8.00 | 1221558 | 5.90 | 696674 | 6.7 |
| 2011 | 305130 | 5.70 | 30769 | 7.00 | 1236558 | 5.20 | 725625 | 6.1 |
| 2012\* | 310000 | 4.20 | 29521 | 3.80 | 1266666 | 3.12 | 759000 | 3.2 |
| Mean | ***313918*** | ***6.09*** | ***30841*** | ***6.68*** | ***1216856*** | ***4.71*** | ***677090*** | ***5.33*** |

\*the rude projection (DZS, 2012; USDA, 2012); \*\*the data of VuSC from 2007-2012

Precipitation in the April-September period of selected sites of Croatia in 1961-1990 period were 402 mm (OS), 463 mm (BJ)) and 500 mm (ZG), while mean air-temperature were 17.8 oC, 16.8 oC and 16.6 oC, respectively (Tables 3 and 4).The analogical data in selected sites of Serbia are 339 mm and 17.6 oC in KI, 356 mm and 17.5 oC in SM, 319 mm and 17.9 oC in NI (Tables 5 and 6). In general, climate of selected sites of Serbia characterized by the lower precipitation and the higher air-temperature during maize growing season (means values of three sites: 453 mm and 17.1 oC, 338 mm and 17.7 oC, for Croatia and Serbia, respectively).

Table 3. Precipitation in Osijek, Bjelovar and Zagreb (Croatia)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Month and year ( LTM = the long-term mean 1961-1990) | | | | | | | | | | | |
|  | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | **LTM** |
|  | Osijek (OS) Weather Bureau: precipitation (mm) | | | | | | | | | |  |
| April | 12 | 137 | 55 | 87 | 3 | 50 | 19 | 71 | 20 | 47 | ***87*** |
| May | 18 | 65 | 46 | 79 | 56 | 67 | 39 | 121 | 81 | 94 | ***58*** |
| June | 44 | 77 | 112 | 91 | 33 | 76 | 63 | 234 | 50 | 68 | ***88*** |
| July | 60 | 44 | 171 | 15 | 27 | 79 | 14 | 32 | 74 | 48 | ***65*** |
| Aug. | 42 | 107 | 238 | 134 | 45 | 46 | 61 | 111 | 5 | 4 | ***59*** |
| Sept. | 51 | 41 | 74 | 11 | 65 | 86 | 10 | 108 | 16 | 32 | ***45*** |
| Σ | *227* | *470* | *696* | *415* | *230* | *404* | *206* | *677* | *246* | *293* | ***402*** |
|  | Bjelovar (BJ) Weather Bureau: precipitation (mm) | | | | | | | | | |  |
| April | 33 | 134 | 62 | 65 | 5 | 31 | 33 | 65 | 34 | 22 | ***63*** |
| May | 31 | 47 | 81 | 108 | 53 | 24 | 50 | 136 | 30 | 94 | ***79*** |
| June | 58 | 105 | 82 | 46 | 60 | 138 | 102 | 178 | 24 | 75 | ***96*** |
| July | 91 | 27 | 123 | 21 | 50 | 59 | 50 | 79 | 59 | 13 | ***78*** |
| Aug. | 25 | 76 | 141 | 144 | 60 | 77 | 21 | 172 | 26 | 5 | ***82*** |
| Sept. | 104 | 62 | 61 | 56 | 154 | 50 | 37 | 204 | 47 | 71 | ***65*** |
| Σ | *342* | *451* | *550* | *440* | *382* | *379* | *293* | *834* | *220* | *280* | ***463*** |
|  | Zagreb-Maksimir (ZG) Weather Bureau: precipitation (mm) | | | | | | | | | |  |
| April | 29 | 136 | 65 | 110 | 2 | 40 | 52 | 63 | 42 | 51 | ***64*** |
| May | 20 | 39 | 66 | 81 | 71 | 44 | 49 | 98 | 70 | 82 | ***79*** |
| June | 66 | 102 | 69 | 40 | 97 | 103 | 68 | 104 | 68 | 128 | ***100*** |
| July | 62 | 70 | 137 | 32 | 49 | 86 | 96 | 53 | 64 | 56 | ***83*** |
| Aug. | 17 | 56 | 175 | 178 | 102 | 55 | 78 | 141 | 16 | 10 | ***95*** |
| Sept. | 112 | 81 | 68 | 68 | 136 | 48 | 22 | 195 | 42 | 120 | ***79*** |
| Σ | *305* | *484* | *578* | *509* | *457* | *375* | *366* | *653* | *301* | *447* | ***500*** |

In accordance with global warming of climate, mean air-temperature in the 2003-2012 decade period (April-Sept.) were the higher in comparison with the correspondingly 1961-1990 period as follows (Tables 4 and 6): +1.0oC (OS), +1.9oC (BJ), +2.0oC (ZG), +1.5oC (KI), +1.2oC(SM) and +1.6oC (NI). Precipitation in 2003-2012 period (April-Sept.) in three sites of Croatia (Table 3) were for 13% lower in comparison with 1961-1990 period (means 398 and 455 mm, respectively), while in three sites of Serbia (Table 5) these values were similar (334 mm and 338 mm, respectively).

Precipitation in the 2003-2012 period during maize growing season (April-Sept.) characterized by very high variation among the years (means of three sites: from 256 mm to 721 mm in Croatia and from 246 mm to 499 mm in Serbia), with prevailing years of the lower values compared to 1961-1990 averages. Analogical comparisons for mean air-temperature were from 17.4 oC to 19.9 oC and from 17.9oCto20.5 oC, respectively. Also, these temperatures in BJ, ZG, KI and NI were the higher compared to means of 1961-1990 in all ten years, while only two years in OS and SM had the lower air-temperatures.

Table 4. Mean air-temperature in Osijek, Bjelovar and Zagreb (Croatia)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Month and year ( LTM = the long-term mean 1961-1990) | | | | | | | | | | | |
|  | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | **LTM** |
|  | Osijek (OS) Weather Bureau: mean air-temperatures (oC) | | | | | | | | | |  |
| April | 11.3 | 11.7 | 11.5 | 12.7 | 13.3 | 12.5 | 14.6 | 12.4 | 13.2 | 12.5 | ***12.7*** |
| May | 20.1 | 14.6 | 17.0 | 16.2 | 18.2 | 18.1 | 18.3 | 16.5 | 16.7 | 16.9 | ***16.5*** |
| June | 24.3 | 19.2 | 19.5 | 20.1 | 22.3 | 21.5 | 19.2 | 20.4 | 20.8 | 22.5 | ***19.5*** |
| July | 22.1 | 21.5 | 21.5 | 23.5 | 23.8 | 21.8 | 23.2 | 23.1 | 22.2 | 24.8 | ***21.0*** |
| Aug. | 23.6 | 21.0 | 19.3 | 19.3 | 22.2 | 21.8 | 22.9 | 21.7 | 23.1 | 24.1 | ***20.3*** |
| Sept. | 15.9 | 15.5 | 17.1 | 17.8 | 14.5 | 15.7 | 19.1 | 15.6 | 20.3 | 18.9 | ***16.6*** |
| Mean | *19.6* | *17.3* | *17.7* | *18.3* | *19.1* | *18.6* | *19.6* | *18.3* | *19.4* | *20.0* | ***17.8*** |
|  | Bjelovar (BJ) Weather Bureau: mean air-temperatures (oC) | | | | | | | | | |  |
| April | 11.7 | 12.0 | 11.6 | 12.6 | 14.0 | 12.2 | 14.9 | 12.2 | 13.5 | 12.6 | ***10.8*** |
| May | 20.7 | 15.8 | 16.6 | 16.0 | 18.3 | 17.8 | 18.1 | 16.4 | 16.9 | 16.7 | ***15.6*** |
| June | 25.3 | 19.7 | 19.7 | 20.3 | 22.4 | 21.2 | 19.2 | 20.3 | 21.3 | 22.4 | ***18.7*** |
| July | 23.0 | 21.2 | 21.4 | 24.0 | 23.2 | 21.9 | 22.4 | 23.3 | 22.0 | 24.1 | ***20.4*** |
| Aug. | 25.2 | 20.9 | 19.0 | 19.0 | 21.6 | 21.7 | 22.6 | 20.9 | 23.0 | 24.1 | ***19.5*** |
| Sept. | 15.9 | 15.7 | 16.8 | 17.7 | 14.5 | 15.1 | 18.5 | 14.9 | 19.9 | 18.1 | ***15.8*** |
| Mean | *20.3* | *17.6* | *17.5* | *18.3* | *19.0* | *18.3* | *19.3* | *18.0* | *19.4* | *19.7* | ***16.8*** |
|  | Zagreb-Maksimir (ZG) Weather Bureau: mean air-temp. (oC) | | | | | | | | | |  |
| April | 10.8 | 11.5 | 11.8 | 12.5 | 13.7 | 12.0 | 14.5 | 12.0 | 13.4 | 12.5 | ***10.6*** |
| May | 19.3 | 14.8 | 16.5 | 16.1 | 18.2 | 17.4 | 18.4 | 16.6 | 16.9 | 16.7 | ***15.3*** |
| June | 23.9 | 19.1 | 19.9 | 20.5 | 22.2 | 20.9 | 19.8 | 20.4 | 21.1 | 22.0 | ***18.5*** |
| July | 23.0 | 21.1 | 21.5 | 23.8 | 22.9 | 21.9 | 22.3 | 23.2 | 22.2 | 24.2 | ***20.1*** |
| Aug. | 25.0 | 21.0 | 18.9 | 18.9 | 21.3 | 21.4 | 22.6 | 20.8 | 23.2 | 24.1 | ***19.3*** |
| Sept. | 15.9 | 16.2 | 16.9 | 17.7 | 14.5 | 15.6 | 18.9 | 15.1 | 20.3 | 18.1 | ***15.8*** |
| Mean | *19.7* | *17.3* | *17.6* | *18.3* | *18.8* | *18.2* | *19.4* | *18.0* | *19.5* | *19.6* | ***16.6*** |

The general statement that the lower maize yields are in close connection with the lower precipitation and the higher air-temperatures, especially in July and August (Shaw, 1988), has been also confirmed in our study (Tables 2-6). Comparisons of the yields in VuSC and Vojvodina in two climatic different growing seasons are typical examples. The highest yields of maize in the decade period were in 2010 both in VuSC and Vojvodina (8.00 and 6.7 t ha-1, respectively) and they are mainly result of adequate precipitation in July and August (143 mm in OS and 150 mm in SM) and the lower temperatures (22.4oC and 22.7oC, respectively). Also, the lowest yields in 2012 (3.80 t/ha and 3,2 t ha-1, respectively) are result of extremely water deficit in July and August, (52 mm and 40 mm, in OS and SM, respectively) and high air-temperatures (24.5 and 24.7oC, in OS and SM, respectively).

Table 5. Precipitation in Kikinda, Sremska Mitrovica and Nis (Serbia)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Month and year ( LTM = the long-term mean 1961-1990) | | | | | | | | | | | |
|  | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | **LTM** |
|  | Kikinda (KI) Weather Bureau : precipitation (mm) | | | | | | | | | |  |
| April | 14 | 104 | 106 | 72 | 1 | 17 | 7 | 50 | 11 | 62 | ***46*** |
| May | 14 | 50 | 52 | 53 | 112 | 32 | 44 | 184 | 48 | 51 | ***56*** |
| June | 27 | 59 | 63 | 48 | 111 | 122 | 115 | 203 | 31 | 20 | ***87*** |
| July | 110 | 65 | 98 | 36 | 40 | 35 | 38 | 72 | 99 | 56 | ***63*** |
| Aug. | 17 | 52 | 130 | 88 | 53 | 21 | 62 | 70 | 11 | 6 | ***47*** |
| Sept. | 91 | 44 | 62 | 28 | 67 | 59 | 5 | 105 | 30 | 15 | ***40*** |
| Σ | *273* | *374* | *511* | *325* | *384* | *286* | *271* | *684* | *230* | *210* | ***339*** |
|  | Sr. Mitrovica (SM) Weather Bureau: precipitation (mm) | | | | | | | | | |  |
| April | 13 | 92 | 67 | 64 | 0 | 52 | 12 | 55 | 20 | 84 | ***51*** |
| May | 30 | 83 | 70 | 31 | 79 | 42 | 45 | 109 | 63 | 71 | ***58*** |
| June | 57 | 67 | 115 | 92 | 85 | 58 | 80 | 127 | 70 | 27 | ***84*** |
| July | 63 | 79 | 72 | 39 | 39 | 61 | 10 | 77 | 94 | 40 | ***65*** |
| Aug. | 38 | 111 | 101 | 156 | 63 | 23 | 43 | 73 | 6 | 0 | ***54*** |
| Sept. | 42 | 40 | 39 | 16 | 93 | 77 | 6 | 77 | 19 | 7 | ***44*** |
| Σ | *243* | *472* | *464* | *398* | *359* | *313* | *196* | *518* | *272* | *229* | ***356*** |
|  | Nis (NI) Weather Bureau: precipitation (mm) | | | | | | | | | |  |
| April | 51 | 56 | 89 | 63 | 6 | 76 | 21 | 80 | 12 | 86 | ***51*** |
| May | 60 | 37 | 104 | 39 | 117 | 45 | 26 | 69 | 71 | 162 | ***67*** |
| June | 25 | 107 | 51 | 68 | 14 | 30 | 119 | 67 | 43 | 6 | ***70*** |
| July | 36 | 44 | 45 | 31 | 8 | 84 | 44 | 36 | 68 | 37 | ***44*** |
| Aug. | 46 | 25 | 85 | 112 | 32 | 62 | 43 | 30 | 4 | 0 | ***43*** |
| Sept. | 54 | 63 | 21 | 16 | 59 | 30 | 36 | 14 | 38 | 12 | ***44*** |
| Σ | *272* | *332* | *395* | *329* | *236* | *327* | *289* | *296* | *236* | *303* | ***319*** |

More detailed analysis of weather characteristics in 2010 and 2012 was shown by distribution of precipitation, mean air-temperatures and absolute maximal temperature over 10-day intervals (Table 7) in Osijek (SHI, 2010, 2012). In the 90-day period from June 11 to September of 2012 precipitation in Osijek was only 81 mm and mean air-temperature 23.9 oC. In the warmest part of the year (third 10-days of August) the absolute maximal air-temperature picked up above 40 oC (Table 7). As affected by these unfavorable conditions, maize plants damaged by heat, lost green color and become dried at end of August. By comparison of the same period of especially favorable the 2010 growing season were found analogical values as follows: 321 mm precipitation and temperatures 21.5 oC and 35.0 oC, respectively (Table 7).

Table 6. Mean air-temperature in Kikinda, Sremska Mitrovica and Nis (Serbia)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Month and year ( LTM = the long-term mean 1961-1990) | | | | | | | | | | | |
|  | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | **LTM** |
|  | Kikinda (KI) Weather Bureau: mean air-temperatures (oC) | | | | | | | | | |  |
| April | 11.1 | 12.1 | 11.6 | 13.3 | 13.0 | 12.6 | 14.9 | 12.4 | 13.2 | 13.3 | ***11.2*** |
| May | 21.0 | 15.4 | 17.3 | 16.5 | 18.6 | 18.1 | 18.6 | 16.9 | 17.1 | 17.3 | ***16.7*** |
| June | 24.1 | 20.0 | 20.0 | 19.8 | 22.5 | 21.9 | 20.1 | 20.5 | 21.5 | 22.9 | ***19.3*** |
| July | 22.9 | 22.4 | 22.2 | 24.0 | 23.8 | 21.9 | 23.4 | 23.4 | 21.9 | 25.3 | ***20.9*** |
| Aug. | 24.4 | 21.5 | 20.1 | 19.9 | 23.2 | 22.8 | 22.8 | 22.0 | 22.8 | 24.0 | ***20.5*** |
| Sept. | 16.6 | 16.0 | 17.7 | 18.3 | 14.8 | 16.1 | 19.2 | 16.0 | 20.1 | 19.8 | ***16.8*** |
| Mean | *20.0* | *17.9* | *18.2* | *18.6* | *19.3* | *18.9* | *19.8* | *18.5* | *19.4* | *20.4* | ***17.6*** |
|  | Sremska Mitrovica (SM) Weather Bureau: mean air-temperatures (oC) | | | | | | | | | |  |
| April | 11.1 | 12.2 | 11.1 | 12.5 | 13.0 | 12.9 | 13.9 | 12.2 | 13.2 | 12.9 | ***11.5*** |
| May | 20.1 | 15.2 | 16.9 | 16.4 | 18.5 | 18.3 | 18.9 | 17.0 | 16.6 | 17.2 | ***16.5*** |
| June | 23.5 | 19.7 | 19.2 | 19.6 | 22.0 | 21.7 | 19.5 | 20.3 | 20.6 | 22.6 | ***19.3*** |
| July | 22.0 | 21.6 | 21.5 | 22.8 | 22.6 | 21.7 | 22.5 | 22.7 | 22.2 | 24.9 | ***20.7*** |
| Aug. | 23.5 | 20.7 | 19.7 | 19.1 | 22.3 | 21.5 | 22.3 | 21.8 | 22.4 | 23.7 | ***20.2*** |
| Sept. | 16.3 | 15.4 | 17.3 | 17.5 | 14.3 | 15.4 | 19.0 | 16.2 | 20.3 | 19.5 | ***16.5*** |
| Mean | *19.4* | *17.5* | *17.6* | *18.0* | *18.8* | *18.6* | *19.4* | *18.4* | *19.2* | *20.1* | ***17.5*** |
|  | Nis (NI) Weather Bureau: mean air-temperatures (oC) | | | | | | | | | |  |
| April | 11.0 | 13.3 | 11.8 | 13.3 | 13.3 | 13.1 | 14.3 | 12.9 | 12.5 | 13.4 | ***11.9*** |
| May | 20.2 | 15.0 | 16.8 | 17.0 | 18.8 | 17.9 | 18.3 | 17.2 | 16.4 | 16.5 | ***16.6*** |
| June | 23.5 | 19.7 | 19.0 | 20.0 | 23.6 | 22.3 | 20.5 | 21.0 | 21.2 | 23.8 | ***19.5*** |
| July | 23.3 | 22.5 | 22.3 | 22.9 | 26.2 | 22.6 | 22.8 | 23.0 | 23.5 | 26.5 | ***21.3*** |
| Aug. | 25.1 | 21.6 | 20.5 | 21.2 | 24.6 | 23.5 | 23.0 | 23.6 | 24.2 | 25.1 | ***21.1*** |
| Sept. | 16.8 | 16.8 | 17.9 | 18.3 | 16.1 | 16.3 | 18.7 | 17.9 | 21.6 | 21.3 | ***17.2*** |
| Mean | *20.0* | *18.2* | *18.1* | *18.8* | *20.4* | *19.3* | *20.0* | *19.3* | *20.0* | *21.1* | ***17.9*** |

The estimated yields of maize in 2012 for Croatia 4.2 t ha-1, Hungary, 4.05 t ha-1, Romania 2.40 t ha-1, and Serbia 3.12 t ha-1 are lower in comparison with the yields in the favorable 2010 growing season for 40%, 37%, 38%, and 44%, respectively (SBS, 2012; USDA, 2012).

Irrigation and soil management practice (ploughing and basic fertilization in autumn instead of spring, growing of more tolerant hybrids to drought stress, etc) could be as possible recommendations for alleviation of drought and high temperature stress in maize.

Table 7. Precipitation, mean air-temperature and absolute maximal air-temp.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Osijek: Weather data in 10-day periods (1st = 1- 10; 2nd = 11–20; 3rd = 21-30/31) | | | | | | | | | |
| Month | Precipitation (mm) | | | Mean air-temp. (oC) | | | Absolute maximal air-temp. (oC) | | |
|  | 1st | 2nd | 3rd | 1st | 2nd | 3rd | 1st | 2nd | 3rd |
|  | The 2010 growing season – especially favorable for maize growing | | | | | | | | |
| May | 2 | 82 | 37 | 17.7 | 13.3 | 18.5 | 27.4 | 24.6 | 28.4 |
| June | 81 | 15 | 139 | 19.0 | 23.8 | 18.4 | 31.9 | 34.2 | 29.3 |
| July | 3 | 4 | 25 | 22.3 | 26.3 | 21.3 | 31.6 | 34.2 | 34.0 |
| Aug. | 89 | 0 | 21 | 22.0 | 23.3 | 20.0 | 32.0 | 31.5 | 35.0 |
| Sept. | 25 | 72 | 11 | 15.8 | 16.5 | 14.4 | 25.7 | 27.2 | 25.0 |
|  | The 2012 growing season – especially unfavorable for maize growing | | | | | | | | |
| May | 14 | 11 | 68 | 18.9 | 14.7 | 17.2 | 31.5 | 30.4 | 26.4 |
| June | 41 | 18 | 9 | 20.6 | 22.7 | 24.2 | 31.2 | 34.0 | 36.0 |
| July | 0 | 1 | 47 | 27.9 | 23.8 | 22.9 | 37.0 | 36.0 | 35.0 |
| Aug. | 0 | 0 | 4 | 26.1 | 21.8 | 24.3 | 40.1 | 34.6 | 40.3 |
| Sept. | 2 | 29 | 2 | 21.0 | 16.9 | 18.7 | 31.5 | 31.5 | 32.2 |

**Conclusion**

Precipitation and temperature regimes are important factors of maize yield in Croatia and Serbia. With this regard, water deficit and the higher temperatures, especially in July and August, is main reason for low yields of maize in the individual years. By this occurrence is more affected Serbia in comparison with Croatia. Global climate warming is also evidenced in our study because in all tested years the higher air-temperatures in the April-September period above the averages 1961-1990 were found in four of six tested sites. Additional negative phenomenon with aspect of maize growing is lower precipitation at the same period in more than 50% years.

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