HOP (*Humulus lupulus* L.) CONES MASS AND LENGHT AT CV. SAVINJSKI GOLDING

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Abstract
In the article the increase of hop cones mass and length at cv. Savinjski golding during forming is presented with regard to weather conditions. Hop cv. Savinjski golding is rather sensitive on the weather conditions with regard to the mass of 100 cones and their length. Stress caused by the shortage of rainfalls and high temperatures, especially during flowering and cones formation (last decade of June and the first two decades of July) cause negative effect on the cones mass and length in the time of technological maturity. The lowest average values in the time of technological maturity at the location Žalec were determined in years with rainfall deficiency in the last decade of June and the first two decades of July, accompanied with high temperatures; mass of 100 cones was 10–11 g dry matter, and the length of cones 30–32 mm. On the other side, higher mass of 100 cones (14–16 g) was obtained in years with above average rainfall quantity in these three decades, or a bit less than average rainfall quantity but average temperatures without extreme ones. Comparing different locations, the trend was the same, but values were a bit lower.
Key words: hop, *Humulus lupulus* L., Savinjski golding, cones, technological maturity, weather conditions, yield

MASA IN DOLŽINA STORŽKOV HMELJA (*Humulus lupulus* L.) SORTE SAVINJSKI GOLDING

Izvleček
V članku je opisano povečevanje mase in dolžine storžkov hmelja sorte Savinjski golding v času oblikovanja storžkov in zorenja glede na vremenske razmere. Masa

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storžkov in njihova dolžina v času tehnološke zrelosti je precej odvisna od vremenskih razmer. Stres zaradi pomanjkanja padavin in visokih temperatur, še posebej v času cvetenja in tvorbe storžkov (zadnja dekada junija in prvi dve dekadi julija) negativno vpliva na maso storžkov in njihovo dolžino v času tehnološke zrelosti. Najnižja masa in dolžina storžkov v času tehnološke zrelosti je bila na lokaciji Žalec določena v letih, ko je bilo v omenjenih treh dekadah malo padavin, temperature pa so bile visoke. V takšnih letih je bila masa 100 storžkov 10–11 g (suhe snovi), dolžina storžkov pa 30–32 mm. Večja masa storžkov (14–16 g) je bila dosežena v letih z nadpovprečno količino padavin v teh treh dekadah oziroma v letu, ko je bila količina padavin v teh treh dekadah sicer nižja od povprečja, vendar so bile zmerne temperature. S primerjavo vrednosti na različnih lokacijah smo ugotovili enak trend, vendar so bile vrednosti nekoliko nižje.
Ključne besede: hmelj, *Humulus lupulus* L., Savinjski golding, storžki, tehnološka zrelost, vremenske razmere, pridelek

1 INTRODUCTION

The harvest of hop plants begins when hop cones reach their technological maturity; when cones have the highest alpha-acid content, reach maximum size and maximum weight. Also a typical structure of essential oils and quality harvesting is guaranteed at that stage. Hops harvested before technological maturity have worst quality and contain too much moisture. Prolonging harvest over the stage of technological maturity results in yellow or brownish cones, lower alpha-acid content and also higher losses due to dispersal and crumbling of hop cones (Čeh and Zmrzlak, 2006).

The start of technological maturity depends on technological measures, weather conditions during growth season (sum of effective temperatures from the first emergence to maturity is at cv. Savinjski golding on average 1698°C), and on a hop variety. Savinjski golding is an early variety; it reaches technological maturity between 10th and 20th of August (Čeh and Zmrzlak, 2006; Čeh and Zmrzlak, 2012; Čeh et al., 2011). According to the archive of Slovenian Institute of Hop Research and Brewing cv. Savinjski golding reached technological maturity in 2006 on 18th August, in 2007 on 10th August, in 2008 on 18th August, in 2009 on 13th August, in 2010 on 20th August, in 2011 on 15th August and in 2012 on 16th August.

The period of technological maturity at Savinjski golding lasts only seven to ten days. Length of the cones increases rather fast and firmly during their forming; the final length depends on the variety and weather conditions. At the same time their weight and the amount of dry matter also increase. Maximum weight of dry matter at Savinjski golding is reached in the middle of technological maturity. At the end

of technological maturity the mass and length of cones begin to decline (Čeh and Zmrzlak, 2006; Čeh and Zmrzlak, 2012; Čeh and Friškovec, 2007c).

The aim of this research is to find out the influence of weather conditions on increasing of hop cones mass and their length, in period from hop cones formation till technological maturity at cv. Savinjski golding.

2 MATERIAL AND METHODS

2.1 Variety Savinjski golding

Savinjski golding is a traditional Slovenian variety, an ecotype of the English Fuggle, which was brought to Slovenia in the 19th century. This variety is recognised for its good agronomic traits in hop production and processing. Resistance on primary infection of downy mildew is low, resistance on its secondary infection is medium. Resistance to powdery mildew and to mild form of verticillium wilt is medium, to lethal form of verticillium resistance is low (Čerenak et al., 2011). Savinjski golding contains 2.8–6.1 % alpha-acids in hop cones, the yield is from 1.2 to 2.2 t/ha. The entry in the National list of Varieties for Savinjski golding was on 31st of Dec 1968 (Descripitive …, 2009). Trade name is Stryian Savinjski golding, abbreviation SSG (Regulation …, 2012).

2.2 Data processing

2.2.1 Increase in the length and mass of hop cones during forming

The sampling of hop cones of cv. Savinjski golding was carried out from 2006 to 2012 at the location Žalec (Slovenian Institute of Hop Research and Brewing - IHPS) from the end of July till mid August or even untill beginning of September in three to four days intervals. Each time cones length and mass were determined. Since the data of hop cones length and mass was not provided at the same dates for each year and because there were unequal gaps (in days) between successive hop sampling days, the data mining was used to estimate missing data for each year.

2.2.2 Mass of 100 cones

The average mass of 100 cones of hop cv. Savinjski golding was analysed comparing the data of different locations at the time of technological maturity from 2006 to 2012. In 2006 there was one location analysed, in 2007 two, in 2008 three, in 2009 four, in 2010 three, in 2011 three and in 2012 four locations. Hop cones were collected at each location at the time of technological maturity. Data was

analysed for all locations for each year and average, minimum and maximum summary statistics was used to compare investigated years with each other.

2.3 Cones sampling and analysing

For each sampling samples of hop cones were gathered from 50 plants diagonally or zigzag in the hop field, from each plant equally from the upper, lower and middle third. Cones were thoroughly mixed and 2 litres of them were put in a plastic bag. For moisure analyse some cones were imediately put in a tight metal box. The moisture content was performed according to Analytica EBC 7.2. (1998). Samples were collected when the dew was gone, and in the days when there was no rainfall. Each time the length of 100 randomly selected cones were wighted and measured. The average value was recorded in millimetres. The mass of 100 cones dry matter was calculated afterwards. The presented data on 100 cones mass in this article refer to their dry matter weight.

2.4 Soil

Soil in the hop field where hop cones were sampled (location Žalec) is alluvial, brown, medium-deep. In most of the identified horizons texture class clayey loam was determined, which ranks this soil among heavy soils. In deeper horizons signs of water retention are noticeable. Soil pH in the upper horizon is 6.8, plant available phosphorus content in the supply class D (33.2 mg/100 g soil), plant available potassium content in the supply class B (15.9 mg/100 g soil), organic matter content 2.7%.

2.5 Weather conditions in the hop growth seasons from 2006 to 2012

In 2006 weather conditions were not favourable for growth and development of hop plants. They were characterized by a relatively low temperature in different periods and high temperatures in July. Spring was cold and wet, in the beginning of June abundant rainfall followed. After warming that followed hop plants grew intensively, but above-average temperatures in the second half of June and in July combined with the lack of rainfall in mid July slowed growth again. In the last decade of June the average temperature was by 6 degrees higher compared to the long term average (of last 40 years), the first two decades of July by two degrees. Hop plants went through phenophases fast, photosynthesis was inhibited. After hot and dry July, beginning of August was relatively cold and rainy (Čeh and Friškovec, 2006; Agrometeorological …., 2006).

Year 2007 was warm with high temperatures in the second half of July; maximum temperatures were even above 35ºC. There were high temperatures fluctuations; temperatures in different periods dramatically increased or decreased (up to 10°C).

The average temperature from April to August was 18.2°C, which is nearly two degrees above the long-term average. During this growing season 473 mm of rainfall fell (116 mm less than is the long-term average), often as heavy showers and storms. There was 116 mm of rainfall in July, and 19 mm in the last decade of June; average temperatures in this time were by 1 to 2 degrees higher compared to the long-term average (Agrometeorological …., 2007; Čeh and Friškovec, 2007a).

During the growth season of 2008 the amount of rainfall was 713 mm (124 mm more compared to the long-term average), but very unevenly distributed. The smallest amount of precipitation occurred in May, 47 mm, the most in June, 228 mm. July was rather wet. The average temperature from April to August was 16.4°C, which is by a good degree more than the long-term average. The second decade of June was by 1.2°C colder than the long-term average, the minimum daily temperature was 9.9°C, while in the last decade of June extremely high temperatures were recorded (in most days maximum daily temperature exceeded 30°C, the average temperature of the decade was by 4.6°C above the long-term average). In the first two decades of July average decades temperatures were by 1 to 2 degrees higher compared to the long-term average (Agrometeorological …., 2008; Čeh and Friškovec, 2008).

In May 2009 relatively high temperatures were recorded, and then they decreased quickly. This reflected in uneven and long flowering of cv. Savinjski golding and consequently in uneven ripening. Compared with the long-term average in 2009 the highest amount of precipitation was recorded in June (174 mm) and in the beginning of July. In the last decade of June and the first two decades of July the average temperatures were comparable to the long-term average, the rainfall amount was by 60 mm higher. In early August, during the maturation of hops, very high temperatures were recorded (Agrometeorological …., 2009; Čeh and Friškovec, 2009).

In all decades of hop growth season 2010 until the end of July, the amount of rainfall was less and the temperatures were higher compared to the long-term average. In particular, the temperatures were high in the first two decades of July, which were accompanied by low rainfall amount (9 mm in both decades together). In the last decade of June there was only 7 mm of rainfall, too. A large deviation from the long-term average (higher temperatures) occurred also in the last ten days of April, the last ten days of May and in the middle of June. In the last ten days of July and in August, the weather conditions were similar to the long-term average (Agrometeorological …., 2010).

In hop growth season in 2011 fell 413 mm of rainfall (timely, quantitatively, and locally very unevenly distributed), which is 173 mm less than the 40-years

average. Rainfall was almost in all decades under the long-term average. The largest rainfall deficit compared to the long-term average was recorded in August, when it was almost 96 mm less rainfall, but also in the second half of June and the first two decades of July. Above-average rainfall was recorded only in the first decade of June and in the third decade of July, when the rainfall deficit was partly covered. Almost throughout whole growth season higher temperatures, than the long-term average, were recorded. In the third decade of July there was a drastic drop of average temperature from 22°C in the second decade to 17°C in the third decade of July (Agrometeorological …., 2011).

Season of 2012 was characterised by extremely low rainfall quantity, which continued already from the autumn 2011. Also March was extremely dry; low rainfall in the form of short showers was recorded on 19th of March, all other days were dry. From April to June there was 338 mm rainfall, which was relatively well distributed. In April, May and June the average temperature was higher than the long-term average. A high deviation from long term average was especially in the last decade of April and in the first decade of May, when the average daily temperature deviated up from the long-term average by 3.2°C and 3.5°C. Very warm was also the second half of June, when maximum daily temperatures exceeded 30°C. The lack of rainfall started again in the last ten days of June, continued in July and August. From 15th of June to 12th of July only 13 mm of rain was recoded. During this period above average temperatures also occurred and that already dictated onset of drought. Whole August was dry and hot. The average daily air temperature was higher than the long-term average in July by 2.1°C, in August by 2.6°C (Agrometeorological …., 2012).

3 RESULTS AND DISCUSSION

3.1 Increase in the length and mass of hop cones during forming

Figures 1 and 2 show changes in the average cone length and in the mass of 100 cones (dry matter) of cv. Savinjski golding from the end of July until late August or even until September for seven successive years (from 2006 to 2012).

Weather conditions in 2006 were not favourable for growth and development of hop plants which resulted in low 100 cones mass (Figure 1). It was the lowest among the investigated years. After cold and wet spring and a hot and dry July, relatively cold and rainy early August followed. That slowed down the increase of alpha acids in the cones, which remained small and lightweight. Therefore, the yield of hops was significantly lower than we anticipated in July (Čeh, 2006). Yield was in some hop fields up to 70 % lower than expected (Čeh and Friškovec,

2006a). As it can be seen on the Figure 1, the cones weight reached its higher values in the middle of technological maturity, although the increase was relatively low (this parameter increased only by 2 g from the end of July to the peak value of 11 g), and then the mass dropped. Also the length of hop cones remain low; 30 mm the most.

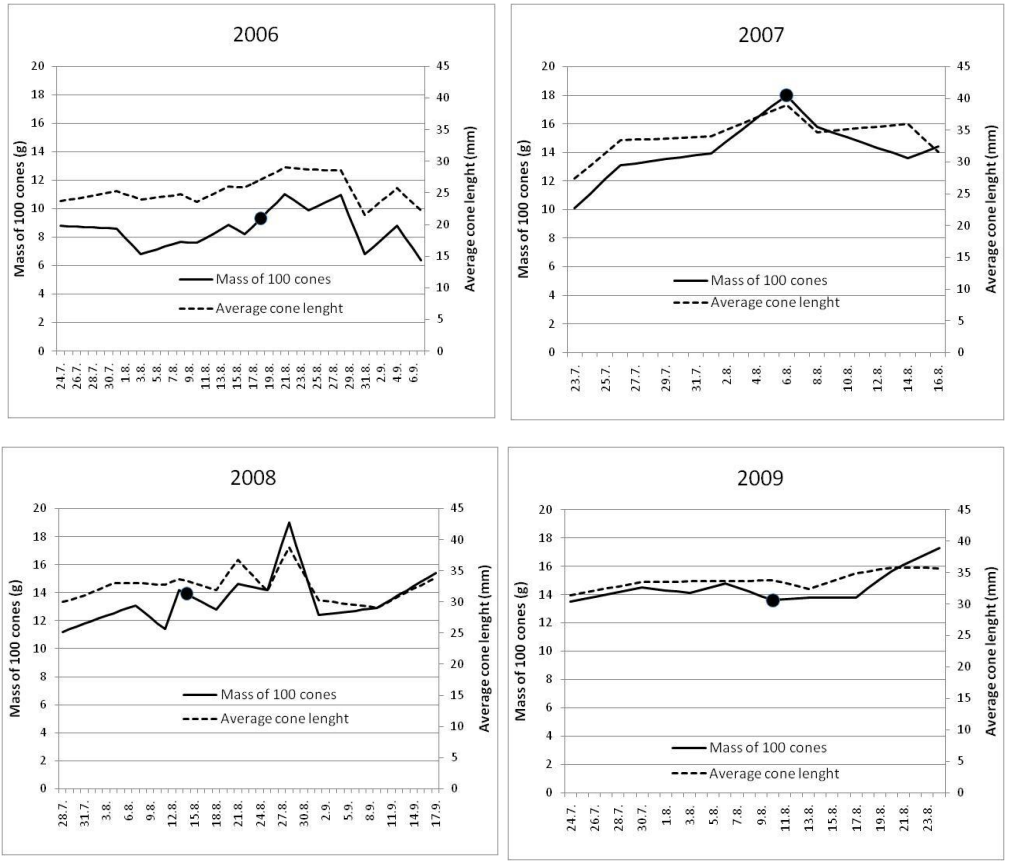

Figure 1: Mass of 100 cones (g dry matter) and average cone length (mm) for hop growth seasons 2006–2009 (July – September) for location Žalec
Slika 1: Masa 100 strožkov (g suhe snovi) in povprečna dolžina storžkov v letih 2006–2009 (julij - september) za lokacijo Žalec

Legend for Figures 1 and 2: Mass of 100 cones; Average cone length; Start of technological maturity

Even if 2007 season was exceptionally warm and there was 116 mm less rainfall in the vegetation period compared to the long term average, the 100 cones mass of Savinjski golding was much higher compared to the year of 2006 (Figure 1).

Because of high temperatures the technological maturity appeared ten days sooner than the year before (Čeh and Friškovec, 2007b; Friškovec and Čeh, 2007). The mass of 100 cones was the highest between 2nd and 10th of August. On 23rd of July the mass of 100 cones was similar then in the previous year, but afterwards it was increasing until 6th of August, when it reached 18 g. The length of cones reached 39 mm.

The wet season of 2008 was favorable for the growth and development of the hop plants cv. Savinjski golding (Čeh and Friškovec, 2008). It can be seen also in the investigated parameters (Figure 1). The mass of 100 cones increased from the end of July and reached the peak from 21st to 28th of August (during the technological maturity) (Čeh, 2008). In that time it was between 14 and even 19 g, similar than in year 2007. The length of hop cones was between 32 and 38 mm.

In 2009 the mass of 100 cones and the length of hop cones almost did not change from the end of July till the end of August. This is due to the fact that there was uneven ripening of hop plants in this season; there were flowers and hop cones on the same plants already in July, which reflected in the same average mass (around 14 g) and length (around 34 mm) no matter when the sampling was done. In early August, during the maturation of hops there were very high temperatures, which had a negative impact on the development of cones. Many cones remain small, light and even immature. Finally, the mass of 100 cones reached 17 g and the length 35 mm, but after the technological maturity.

In 2010 low mass of 100 cones and also the length of cones were reached. Obviously high temperatures in the first two decades of July, accompanied by low rainfall amount, did not have positive impact on those two parameters. Mass of 100 cones reached 11 g maximum and the length 30 mm (Figure 2), similar as in 2006. At the end of July the mass was only 7 g, and also slow increase afterwards can be seen.

In 2011 the mass of 100 cones was also 7 g at the end of July, then it increased, but it remained low; it reached 12 g on 11th of August and stayed on this level for about a week. The length of cones reached 32 mm on 8th of August and stayed on this level for 10 days (Figure 2). Again, the lack of precipitation and higher temperatures than the long-term average throughout the whole growth season, especially in the second half of June and the first two decades of July, accompanied with lack of rainfall, had negative effect on two investigated parameters of cv. Savinjski golding.

In spite of extreme drought conditions in 2012 hop cones length reached 33 mm and their mass reached 13.6 g, but after the technological maturity. In the time we had to harvest hop plants, these parameters were 30 mm and 10–11 g, respectively.

The length of cones and their mass were increasing steadily from the beginning of August to the end of monitoring on 18th of August (Oset Luskar and Friškovec, 2012a; 2012b).

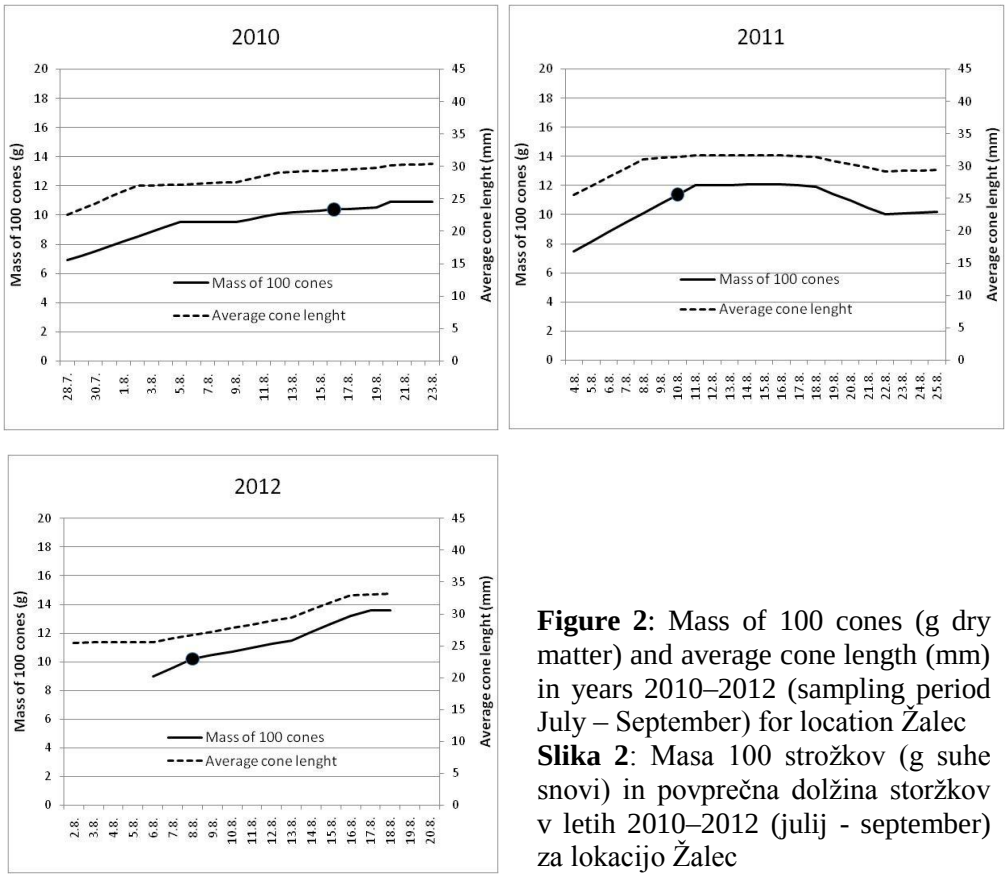

Figure 2: Mass of 100 cones (g dry matter) and average cone length (mm) in years 2010–2012 (sampling period July – September) for location Žalec
Slika 2: Masa 100 strožkov (g suhe snovi) in povprečna dolžina storžkov v letih 2010–2012 (julij - september) za lokacijo Žalec

Therefore, the highest average mass of 100 cones occurred in 2007, 2008 and 2009. Maximum mass of 100 cones was observed in these years, too; in 2008 followed by 2007 and 2009, resulting in 19.0, 18.0 and 17.3 g. The highest cones length in technological maturity was observed in 2007, followed by 2009 and 2008, resulting in 39.0, 38.8 and 35.8 mm.

3.2 Mass of 100 cones at the technological maturity

At the stage of technological maturity different locations through Lower Savinja valley were taken into account with regard to 100 cones weight. Locations were different in different years (from 2006 to 2012) and there was also different number of locations. The highest average mass of 100 cones, when taking into

account all locations for each year, occurred in 2007 (13.4 g), followed by 2009 (12.8 g), 2006 (11.0 g), 2008 (10.7 g), 2011 (10.4 g), 2010 (9.8 g) and 2012 (8.6 g) (Figure 3).

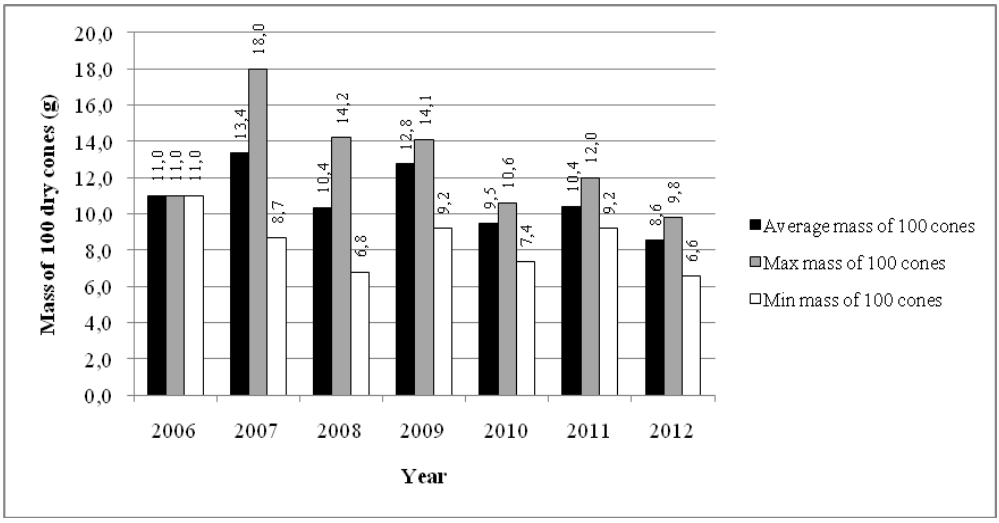

Figure 3: Average, maximum and minimum mass of 100 dry cones for seven successive years (2006–2012) for all locations at the stage of hop plants technological maturity.
Slika 3: Povprečna, največja in najmanjša masa 100 suhih strožkov glede na leto (2006–2012) za vse preučevane lokacije v času tehnološke zrelosti

In 2006 the data was available only for location Žalec (11 g) and in 2007 for two locations (8.7 and 18 g). In 2008 there were three locations considered; mass of 100 cones was 6.8, 10.1 and 14.2 g. In 2009 four locations were considered with the mass of 9.2, 13.6, 14.1 and 14.1 g, in 2010 three locations were considered, resulting in mass of 7.4, 10.4 and 10.6 g, in 2011 three locations were considered, resulting in 9.2, 10.1 and 12.0 g and in 2012 the mass for four locations was 6.6, 8.9, 9.0 and 9.8 g.

Considering individual sampling locations (Figure 3), the highest mass of 100 dry cones was observed at one location in 2007 at 18.0 g and the lowest mass in 2012 at 6.6 g. Maximum average mass of 100 cones, reached in 2007, was followed by 2009, 2006, 2008, 2011, 2010 and 2012 with 12.8, 11.0, 10.4, 10.4, 9.5 and 8.6 g, respectively.

4 CONCLUSIONS

Hop cv. Savinjski golding is rather sensitive on the weather conditions with regard to 100 cones weight and their length. Stress due to the shortage of rainfall and high temperatures, especially during flowering and cones formation (last decade of June and the first two decades of July) have negative effect on the cones mass and length in the time of technological maturity. The lowest average values were determined in 2006, 2010, 2011 and 2012. In these years mass of 100 cones was 10–11 g, and the length of cones 30–32 mm. In all these years there was shortage in rainfall in the period from the last decade of June to the first two decades of July, accompanied with high or even extreme temperatures; the quantity of rainfall in these three decades was 99, 17, 52 and 99 mm, respectively.

On the other side, in 2007, 2008 and 2009 in the same three decades there was above average rainfall quantity, or at least 2/3 of average rainfall quantity accompanied with average temperatures (without extreme ones). In these years mass of 100 cones was 14–16 g. Even if the temperatures in these three decades were extreme in some days and higher compared to the long-term average, the above average rainfall amount (159 mm) obviously impacted positively to the mass of 100 cones (in 2008). In 2007 the amount of rainfall was not so high (it was 2/3 third of long term-average; 84 mm), but there were not extreme temperatures; the period was by 1 to 2 degrees warmer compared to the long-term average. In 2009 the amount of rainfall in these three decades was 192 mm and temperatures were similar then the long-term average.

Comparing different locations in mass of 100 cones in technological maturity the values were lower than at the location Žalec itself, but the trend was the same; the highest average mass of 100 cones, when taking into account all sampling locations for each year, occurred in 2007 (13.4 g), followed by 2009 (12.8 g), 2006 (11.0 g) and 2008 (10.8 g). (The location Žalec reached the highest values of mass of 100 cones each year and in 2006 the sampling was done only at this location, so it can be considered that it would be lower in the scale if the sampling would be done at more locations.) In years 2011 (10.4 g), 2010 (9.8 g) and 2012 (8.6 g) low average mass of 100 cones were detected.

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