In: Sugar Beets
Editor: Lindsey Brooks
ISBN: 978-1-63463-499-1

Chapter 6

SUGAR BEET QUALITY IN DEPENDENCE ON THE EFFECTIVENESS OF FUNGICIDES AND GENOTYPE ON *CERCOSPORA BETICOLA* SACC

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ABSTRACT

Sugar beet is one of two the most important industrial cultures for sugar production. A large number of factors have an impact on the achieved results in the sugar beet production, whereby the most important one is the appearance and development of leaf disease caused by *C. beticola* Sacc. In the area where sugar beet is grown, the damage by this fungal plant patogen is large. It depends on the cropping practices, abiotic factors, quality and quantity of the composition of microorganisms in the soil and the disease control measures. Application of tolerant hybrids has become a rule in the areas where it is cultivated sugar beet. By breeding were obtained tolerant hybrids against this pathogen, on the other side, this tolerance did not influence the yield reduction, as it was the case with the first obtained tolerant hybrids to fungus *C. beticola* Sacc. Application of fungicides is necessary for sensitive and tolerant sugar beet hybrids. The efficiency of the treatment depends on the application time, number of applications and the choice of fungicide - contact or sistemic. Furthermore, it is extremely important to choose the right active substance of fungicide, which means do not use twice the same active substance, or combine two or more active substances in order to avoid the development of resistance. For these reasons, the aim of this study was to determine root yield and root quality of sugar beet under different climate and soil conditions in dependence of fungicide efficiency and the tolerance to fungus *Cercospora beticola* Sacc. of the studied hybrids. Research of production values 8 hybrids were performed on eutric brown soil in eastern Croatia in the conditions of natural infection with a pathogenic fungus *Cercospora beticola Sacc.* with and without fungicide application since 2010. until 2012. Hybrids involved in the experiments are unequal tolerance to the fungus *C. beticola* and

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they are ownership of four selection houses that sell sugar beet seed in the Republic of Croatia. Weather conditions during the research were significantly different. The first was with increased, while the remaining two with small amounts of rainfall compared to the long term average. In all three years monthly air temperatures during the growing period were elevated, especially 2012th year. The obtained results show strong dependence of yield and quality of the roots of through vegetation of conservation leaf, hybrids and year. Because of damage to the leaves, on variants where no treatment was carried out in relation to the well-preserved variant with three treatments, root yield was reduced by an average of 15.92 t ha $^{-1}$ (20,64%), sugar content 1,61 (rel. 10,37%) and sugar yield for 3,07 t ha^{-1} (30,67%). Damages due to omitted fungicide application were highly significant for all hybrids, and the repeated use of fungicides to combat *C. beticola* Sacc., it is still mandatory and highly cost-effective measures in sugar beet production. On average of research by highest root yields hybrids were Boomerang, Colonia, KWS and Sandor. The highest sugar content were found in Colonia KWS, Asketa and Boomerang. Content of sugar in molasses best hybrid was Colonia KWS. By pure sugar yield significantly better than the others were hybrids Colonia KWS and Boomerang.

Keywords: sugar beets, hybrids, *Cercospora beticola* Sacc., yield, root quality

INTRODUCTION

Sugar beet is one of the most important industrial cultures in Croatia and the only raw material for sugar production. Sugar beet is grown on about 25.000 ha annually. In the last five years, the average root yield was about 52.0 t ha^{-1}, while the sugar content was about 15.67%. Neither the producers nor the root processors are satisfied with such results. A large number of factors have an impact on the achieved results in the sugar beet production, whereby the most important one is the appearance and development of leaf disease caused by *C. beticola* Sacc. In the area where sugar beet is grown, the damage by this fungal plant patogen is large. It depends on the cropping practices, abiotic factors, quality and quantity of the composition of microorganisms in the soil and the disease control measures. Sugar beet leaf spot is very harmful in all European countries with warm and humid summers (Ruppel, 1995). The most obvious damages are on the leaf surfaces. Generally, higher loss of leaf-mass is registered in cases of early and strong infections. Leaf-mass reduction leads to lower photosynthesis activity which results in lower yields and quality of sugar beet. Root yield reduction might be about 15-30% (Hoffman and Schmulterer, 1999, Sharifi et al., 2007, Wolf et al., 1998), but it might be also about 60% (Yoshimura et al., 1992). Kristek et al. (2006, 2008), testing a number of hybrids in conditions of natural infection with and without fungicide treatment, recorded a root yield loss of about 13%. Sugar content decrease might be about 2% (Wolf et al., 1998), or about 3-7% according to Yoshimura et al. (1992). Kristek et al. (2006, 2008) reported about mean sugar content decrease of 1.35%. Rešić (2003) reported that sugar content of the control plot was 0.40 - 1.35% lower in comparison with the once treated plot and 0.74 - 1.83% lower in comparison with the twice treated plot. Root yield loss and sugar content decrease in combination with increase of molasses elements at the same time results in pure sugar yield loss of 40 - 50% (Wolf, 1998). Biancardi et al. (2001) tested six hybrids with different levels of tolerance without fungicide application and with fungicide applications every 10 and 20 days after the incidence of disease and registered that the impact of genotype on pure sugar yield was always lower than the impact of fungicide applications

on pure sugar yield. Control measures in leaf spot suppression includes cultural practices, seeding of tolerant hybrids and the use of fungicides. Preventive cropping practices include sowing of healthy and fungicide treated seeds, proper crop rotation and timely soil preparation, as well as timely organised fertilisation and weed control. A quality nutrition directly affects the sugar beet's health.

Application of tolerant hybrids has become a rule in Croatia. By breeding were obtained tolerant hybrids against this pathogen, on the other side, this tolerance did not influence the yield reduction, as it was the case with the first obtained tolerant hybrids to fungus *C. beticola* Sacc. Application of fungicides is necessary for sensitive and tolerant sugar beet hybrids aswell (Kristek et al., 2006, 2008). The efficiency of the treatment depends on the application time, number of applications and the choice of fungicide - cantact or sistemic. Furthermore, it is extremely important to choose the right active substance of fungicide, which means do not use twice the same active substance, or combine two or more active substances in order to avoid the development of resistance.

As regards the development of genetic tolerance, it is important to note that breeders tried to increase the genetic potential of hybrids, in the first place, and hybrids for most important quantity and quality properties, thereafter they tried to increase their resistance to most important diseases (*Rhizomania, C. beticola, R. solani*). Breeding for resistance to *C. beticola* and other diseases at all is very complicated because it is a relation between sugar beet, as a host plant, and the pathogen. Difficulties come from the fact that both organisms have their own heratibility and variability. Resistance to pathogenic fungus *C. beticola* is a very complex trait. Smith and Gaskill (1970) reported that the resistance to this fungus is controlled with 4-5 pairs of genes. In breeding it is often not possible to unite resistance with maximum root yield and root quality. As root yield and root quality have priority we still can not talk about totally tolerant sugar beet hybrids. So Kristek et al. (2006), testing the resistance of 26 sugar beet hybrids owned by the most significant plant breeding houses in Europe, concluded that the used hybrids do not show sufficient tolerance to fungus *C. beticola* and that in sugar beet production the application of fungicides can not be excluded.

The aim of this study was to determine root yield and root quality of sugar beet under different climate and soil conditions in dependence of fungicide efficiency and the tolerance to fungus *Cercospora beticola* Sacc. of the studied hybrids.

MATERIALS AND METHODS

The research was conducted during the field experiments set up in eastern Croatia in the period from 2010 to 2012.

The experiment involved 8 different hybrids (Table 1) and 3 ways to suppress the pathogenic fungus *Cercospora beticola* Sacc. via fungicides (1-3 treatments). Considering the technical side of performing experiments, i.e., the use sowing machines and sprayers, the experiment was set up in a split-block scheme with 4 replications. Hybrids used in the experiment were declared as tolerant to *C. beticola* and remain the property of companies selling seed in Croatia. Only one, slightly older hybrid Belinda is declared sensitive to this disease.

Table 1. Hybrids of sugar beet in the study and declared their properties

No.	Hybrid	Company	Type*	Tolerance**
1	Belinda	KWS	Z	R
2	Colonia KWS	KWS	Z	R, Cr
3	Elvis	Strube	Z	R, Cr
4	Sandor	Strube	NZ	R, Cr, Aph
5	Boomerang	SES - Van der Have	N	R, Cr, Rh
6	Giraf	SES - Van der Have	Z	R, Cr
7	Asketa	Syngenta Seed - Hilleshög	Z	R, Cr, Rh
8	Gazeta	Syngenta Seed - Hilleshög	Z	R, Cr, Rh

**R - Rhizomania; Cr – Cercospora beticola Sacc.; Rh – Rhizoctonia solani Kühn;
Aph - Aphanomyces cochlioides Drechsler
* Z = low yield and high sugar („Sweet type“)
N = intermediate in root yield and sugar content („normal type“)
NZ = between the N type and Z type.

We investigated three variants of fungicide application in protecting against pathogen *C. beticola* Sacc.:

1. control (not treated)
2. treated with fungicide one times
3. treated with fungicide three times

Experiments were set up on the eutric brown soil with the following characteristics: pH_{KCl} - 5.22; pH_{H2O} - 6.48; humus content - 2.39%; AL – P_2O_5 - 21.40 mg/100g soil; AL – K_2O - 26.63 mg/100g soil. Size of the basic plots in the experiment was 72 m^2, and consisted of 12 rows: width – 6 m, length – 12 m. The rounded plot was 20 m^2 (8 rows = 4 m wide x 5 m long).

Sugar beet sowing was conducted via pneumatic seed drill in the second half of March with the sowing row of 15.7 cm. Ordinary fertilization for this area was conducted; with the primary tillage was added up to 500 kg ha^{-1} of NPK 5:15:30 and 80 kg ha^{-1} of urea, before sowing was added up to 150 kg ha^{-1} of KAN (27% N) and 70 kg ha^{-1} of KAN was added in top- dressing. In total was added up to 121 kg ha^{-1} of N_2, 75 kg ha^{-1} of P_2O_5 and 150 kg ha^{-1} of K_2O. Weed control was obtained by applying herbicides after emergence and hand hoeing in the stand regulation. Herbicides which were used: Betanal Progress OF (Fenmedifam 9% + desmedifam 7% + etofumesat 11%) – 0,6 l ha^{-1}, Lontrel 300 SL (Klopiralid) – 0,25 l ha^{-1} and Safari WG (Triflusulfuron metil) – 30 g ha^{-1}, and combined on many occasions. Pest control was not necessary as the seeds of hybrids were processed by synthetic insecticide Gaucho FS 600 (imidaklopirid, 600 g l^{-1}), which has full protection in sensitive stages of growth and development of sugar beet. Protection against *C. beticola* Sacc. pathogens was performed when 10% of leaves showed the presence of symptoms. The first fungicide treatment was performed on July 7 (2010), August 2 (2011) and July 27 (2012) in variant 2 and 3 with - 0.8 l ha^{-1} of Eminent 125 EW (tetrakonazol 125 g l^{-1}). The second treatment with 0.4 l ha^{-1} of fungicide Sphera 535 EC (trifloksistrobin 375 g l^{-1} + ciprokonazol 160 g l^{-1}) was performed on July 28 (2010), August 22 (2011) and August 20 (2012) only in variant 3. The third

treatment with 1.2 l ha^{-1} of fungicide Opus team (epoksikonazol 84 g l^{-1} + fenpropimorf 250 g l^{-1}) was applied only in variant 3 on August 20 (2010), August 15 in 2011 and August 12 in 2012. In mid-September was performed the visual assessment of *C. beticola* Sacc. pathogens presence and leaf damages using the scale Kleinwanzlebener Cercospora Tafel with a grade from 0 to 5.

The harvest was carried out in mid (16-18) October. After harvest the samples were taken to determine the root yield and quality. Using standard methods were determined the content of sugar, potassium, sodium and alpha-amino nitrogen (AmN) in the laboratory "Venema". Sugar content was determined by saccharimeter by cold digestion, the content of potassium and sodium via flame photometer and AmN content was determined by colorimetric method "blue number". Sugar yield and sugar content in molasses was determined according to Braunschweiger formula (Buchholz and associates, 1995).

The obtained data were processed by modern statistical methods (variance analysis) using computer programs for each year separately and the total for all three years. The year in which the experiments were carried out with each other were significantly differ by weather conditions.

Two years were dry with below-average monthly precipitation, and one (2010) was damp with 654 mm of rainfall in vegetation, which is even more than the average 244 mm/year. Particularly unfavorable for sugar beet growth and development was 2012 year that followed after dry 2011 as it came with a small reserve of water in the soil, and rainfall in the vegetation was less than the standard average. Besides, monthly mean temperature in the vegetation was significantly higher (2-3 °C) than the multi-year average temperature; in July and August it exceeded 24 °C, which is 6 °C higher than is needed for sugar beet in this period. During all three years of study in the first part of growing season (from emergence to the development of maximum leaf area), weather conditions were favorable for steady emergence and rapid foliage growth. The growth of broad roots significantly varied from year to year. Lack of precipitations in 2010 and now at the development stage is favorable for broad root growth, but in 2012 in two months (July, August) the precipitations amounted only 52 mm of rainfall. So little rainfall and very high temperatures almost completely prevented from the broad roots growth. The remaining two years at this stage provided equal and average conditions for the mass beets growth. At the stage of maximum sugar concentration, sugar beet needs little rainfall, only 35-40 mm per month. Poor conditions for maturation provided in moist 2010 and very dry 2012 thickened the root which was very dehydrated so precipitation that fell in September and October led only to a dilution of cell sap, and not to an increase in sugar content. As a result this year extracted beets turned out to be not mature enough because of high content of sodium and alpha-amino nitrogen.

RESEARCH RESULTS

Achieved research results significantly varied depending on the weather conditions among the years and explored factors, such as the number of fungicide applications in measures of protection against leaf spot caused by *Cercospora beticola* Sacc. and hybrids. The impact of these factors will be analyzed through the most important parameters that determine the results in the production and processing of sugar beet.

ROOT YIELD

During a three-years research an average root yield of about 69.41 t ha^{-1} was realized (Table 2), which considering to the soil characteristics and production technology did not show particularly good production results.

Table 2. Root yield (t ha^{-1}) depending of hybrid, protection of fungicides and year

Hybrid (A)	Variant (B)	Year (C)			*Average*
		2010	2011	2012	
Belinda	1	73.38	51.03	42.91	55.77
	2	85.63	64.12	50.73	66.83
	3	96.07	68.48	57.30	73.95
Average		*85.03*	*61.21*	*50.31*	*65.52*
Colonia KWS	1	83.10	78.72	52.75	71.52
	2	93.07	82.00	57.15	77.41
	3	105.53	91.53	59.32	85.46
Average		*93.90*	*84.08*	*56.41*	*78.13*
Elvis	1	58.09	58.61	35.12	50.61
	2	63.91	66.20	42.84	57.65
	3	65.27	68.17	45.30	59.58
Average		*62.42*	*64.33*	*41.09*	*55.95*
Sandor	1	82.71	73.20	48.96	68.29
	2	97.80	85.79	51.62	78.40
	3	118.27	86.44	58.40	87.70
Average		*99.59*	*81.81*	*52.99*	*78.13*
Boomerang	1	84.45	77.08	55.08	72.20
	2	98.69	79.44	63.55	80.56
	3	106.20	83.72	60.30	83.41
Average		*96.45*	*80.08*	*59.64*	*78.72*
Giraf	1	62.08	58.96	46.00	55.68
	2	75.71	72.75	55.42	67.96
	3	87.80	76.73	61.20	75.24
Average		*75.20*	*69.48*	*54.21*	*66.29*
Asketa	1	69.35	72.07	43.15	61.51
	2	76.96	79.25	49.65	68.62
	3	95.07	84.64	52.80	77.50
Average		*80.45*	*78.65*	*48.53*	*69.21*
Gazeta	1	60.02	61.25	40.93	54.07
	2	70.20	69.23	46.03	61.82
	3	98.67	72.95	50.98	74.20
Average		*76.30*	*67.81*	*45.98*	*63.36*
Total average 1		71.64	66.37	45.61	61.21
Total average 2		82.75	74.85	52.12	69.91
Total average 3		96.61	79.08	55.70	77.13
Total average		*83.67*	*73.43*	*51.15*	*69.41*
$LSD_{0,05}$		A - 4.25 B - 3.49	A - 4.08 B - 3.99	A - 3.83 B - 2.74	A – 4.98 B – 4.23 C – 3.95
$LSD_{0,01}$		A – 5.59 B – 4.61	A – 5.38 B – 5.27	A – 5.06 B – 3.60	A - 6.58 B - 5.59 C - 5.26

Main reason for this, primarily, were unfavorable weather conditions (drought stress and high air temperatures) during two years of research. This is the main reason for great yield variability among years. The highest mean root yield was 83.67 t ha^{-1} in 2010, where during the vegetation the largest amount of rainfall was registered. The smallest mean root yield was achieved in 2012 and was about 51.15 t ha^{-1}, in that year the amount of rainfall was below long term average with unfavourable water distribution and higher mean air temperatures. Achieved mean root yield in the favourable year (2010) was about 63.58% higher than the mean root yield in the less favourable year (2012).

This data tells about very strong influence of weather conditions on sugar beets root yield. An significant impact on the root yield had the protection of leaf disease caused by *C. beticola* Sacc. On the treatment without fungicide application (variant 1), in research average, the lowest root yield of 61.21 t ha^{-1} was achieved. The yield reduction of beets on this treatment, because of leaf damages in regard to the treatment with repeated fungicide applications (variant 3), where was mostly little damages at the end of vegetation, was in average about 15.92 t ha^{-1} or 20.64%. Already one fungicide application (variant 2) reduced leaf damages, so the yield reduction on variant 1 compared to variant 2 was about 8.70 t ha^{-1} or 12.45%. These data show that by such agro-climatical conditions one fungicide application is not enough. This is especially valid for humid years like 2010 where on treatments with one application the root yield was lower by 13.86 t ha^{-1} or 14.05% compared to treatments with three applications. In the remaining two years the difference between variant 2 and variant 3 was much smaller (about 4 t ha^{-1} or by 6-7%). The differences in root yield and between studied hybrids are significant. In research average, the highest root yield (78 t ha^{-1}) was achieved with the following hybrids: Boomerang, Colonia KWS and Sandor. At the same time in the climatic favourable year 2010 with good protection against *C. beticola* Sacc. these hybrids achieved high root yields - over 100 t ha^{-1}. The lowest root yields on treatments without fungicide application, in an three-years average, were achieved with hybrid Belinda which is declared to be sensitive to *C. beticola* (55.77 t ha^{-1}), but also with tolerant hybrids to *C. beticola* like Elvis (50.61 t ha^{-1}), Gazeta (54.07 t ha-1) and Giraf (55.68 t ha^{-1}).

Sugar Content

The average sugar content in sugar beets during all years of research and for all hybrids was low and amounted only 14.88% (Table 3). Weather conditions had significantly affected on sugar content in roots. The highest sugar content of 15.52% was achieved in 2012, in which the lowest, only 13.93%, was achieved in 2010. During the research highest sugar content average was achieved by hybrid Colonia KWS and amounted 15.40%. In the same range, with no significant differences in sugar content, were two more hybrids (Asketa i Boomerang). The lowest sugar content average during the research was achieved by hybrids Sandor and Giraf.

Fungicide application significantly affected on sugar content. Lowest mean sugar content of about 13.92% was achieved on treatments without fungicide application and highest mean sugar content of about 15.53% was achieved on treatments with three fungicide applications. With just one fungicide application against disease caused by *Cercospora beticola* Sacc. the sugar content was, compared to the control, significantly increased, in average by 1.27%. The largest increase was in humid 2010 and the average for all hybrids amounted 1.47%.

Table 3. Sugar content (%) depending of hybrid, protection of fungicides and year

Hybrid (A)	Variant (B)	Year (C)			*Average*
		2010	2011	2012	
Belinda	1	11.90	13.65	14.95	13.38
	2	13.81	15.10	15.75	14.89
	3	14.59	15.21	16.07	15.29
Average		*13.43*	*14.65*	*15.47*	*14.52*
Colonia KWS	1	14.01	14.72	15.00	14.58
	2	15.08	15.77	16.10	15.65
	3	15.65	15.99	16.31	15.98
Average		*14.91*	*15.49*	*15.80*	*15.40*
Elvis	1	12.29	14.95	14.51	13.92
	2	13.80	16.12	15.78	15.23
	3	14.44	16.44	16.17	15.68
Average		*13.51*	*15.84*	*15.49*	*14.94*
Sandor	1	12.23	13.47	14.07	13.26
	2	14.12	14.98	15.41	14.84
	3	14.49	15.00	15.72	15.07
Average		*13.61*	*14.48*	*15.07*	*14.39*
Boomerang	1	12.82	14.83	15.52	14.39
	2	14.62	15.94	15.70	15.42
	3	14.93	16.11	15.94	15.66
Average		*14.12*	*15.63*	*15.72*	*15.16*
Giraf	1	12.40	13.69	14.17	13.42
	2	13.91	15.39	15.49	14.93
	3	13.14	15.99	15.70	14.94
Average		*13.15*	*15.02*	*15.12*	*14.43*
Asketa	1	14.07	14.58	15.12	14.59
	2	14.97	15.66	16.00	15.54
	3	15.33	16.03	16.08	15.81
Average		*14.74*	*15.42*	*15.73*	*15.32*
Gazeta	1	12.50	14.19	14.88	13.89
	2	13.69	15.39	15.98	15.02
	3	15.54	15.51	16.30	15.78
Average		*13.91*	*15.03*	*15.72*	*14.89*
Total average 1		12.78	14.26	14.73	13.92
Total average 2		14.25	15.44	15.78	15.19
Total average 3		14.76	15.79	16.04	15.53
Total average		*13.93*	*15.20*	*15.52*	*14.88*
$LSD_{0,05}$		A – 0.34 B – 0.45	A – 0.25 B – 0.36	A - 0.18 B - 2.74	A – 0.35 B – 0.33 C – 0.39
$LSD_{0,01}$		A – 0.50 B – 0.45	A – 0.33 B – 0.47	A – 0.31 B – 0.24	A – 0.46 B – 0.44 C – 0.51

A significantly increase in sugar content was also achieved on treatments with three fungicide applications. This treatment compared to the one with only one fungicide application showed that sugar content was in average increased by 0.34%. The increase in

sugar content due to implemented disease control depended also largely on hybrids. In three-years average during the research, variant 3 compared to variant 1, highest increase in sugar content was achieved with hybrids Belinda (1.91%), Gazeta (1.89%) and Sandor (1.81%), which in the lowest increase in sugar content was achieved with hybrids Asketa (1.22%), Boomerang (1.27%) and Colonia KWS (1.40%). It follows that neither the increase in sugar content within fungicide application does not depend on the characteristics of declared tolerance to *C. beticola*, also the lowest mean sugar content on treatments without fungicide application was achieved with three hybrids (Sandor, Belinda and Giraf). With three fungicide applications in 2012 achieved mean sugar content was about 16.04% with highest values by following hybrids: Colonia KWS (16.31), Gazeta (16.30%) and Elvis (16.17%).

SUGAR IN MOLASSES

The average sugar content in molasses during the research was about 2.57% per beet (Table 4), which can be assessed as a good result. This indicator was mostly influenced by weather characteristics during growing season, then by hybrid, in which the influence of fungicide application was small. The highest sugar content in molasses per beet (3.20%) was achieved in 2012, where beets because of unfavourable weather characteristics (high air temperatures and drought) during the second half of vegetation had disrupted flow of development, so the sugar beets at harvest were unripe with high content of sodium and alpha-amino nitrogen. During 2013 in average 1% more sugar was lost compared to 2012. Hybrids with extremely high sugar content in molasses values were: Gazeta, Asketa, Belinda and Giraf (3.39% - 3.25%), whereby significantly better results were achieved with hybrid Colonia KWS (2.68%). The average loss of sugar in molasses per beet in 2010 was about 2.21%, which is a very good result. Highest losses in 2010 were achieved with hybrids Sandor and Elvis (2.51% and 2.46%), which are still good results.

Sugar Yield

The average pure sugar yield during the research was about 8.58 t ha^{-1} (Table 5) with high variations among years which cannot be evaluated as satisfactorily. Yield variations are mainly result of extreme weather characteristics, but also of unequal hybrid reactions to stressful conditions.

Highest pure sugar yield average of about 9.92 t ha^{-1} was achieved in 2010 with above-average amounts of rainfall during the vegetation, whereby the lowest yield average of about 6.33 t ha^{-1} was achieved in 2012 with very low amounts of rainfall and high air temperatures during the vegetation. Compared to other hybrids in the trial, significantly higher pure sugar yield average during three years of research was achieved with hybrids Colonia KWS (10.25 t ha^{-1}) and Boomerang (9.92 t ha^{-1}).

Analyzed by individual years of research, during the most favourable year of research (2010) significantly higher sugar yields, compared to other hybrids in the trial, were achieved with hybrids Colonia KWS (12.13t ha^{-1}) followed by Boomerang (11.63 t ha^{-1}) and Sandor

(11.19 t ha^{-1}). In the year with the lowest yields (2012), highest yields (higher than 7 t ha^{-1}) were achieved with hybrids Colonia KWS and Boomerang.

Table 4. Sugar in molasses (% per beet) depending of hybrid, protection of fungicides and year

Hybrid (A)	Variant (B)	Year (C)			*Average*
		2010	2011	2012	
Belinda	1	2.04	2.25	3.24	2.51
	2	2.29	2.14	3.34	2.59
	3	2.01	2.28	3.42	2.57
Average		*2.11*	*2.22*	*3.33*	*2.55*
Colonia KWS	1	2.00	2.21	2.67	2.29
	2	1.90	2.21	2.64	2.25
	3	2.26	2.14	2.71	2.37
Average		*2.05*	*2.19*	*2.68*	*2.30*
Elvis	1	2.18	2.23	3.14	2.52
	2	2.75	2.14	3.07	2.65
	3	2.47	2.28	3.17	2.64
Average		*2.46*	*2.22*	*3.12*	*2.60*
Sandor	1	2.51	2.39	3.21	2.70
	2	2.56	2.23	3.12	2.63
	3	2.48	2.14	3.18	2.60
Average		*2.51*	*2.25*	*3.17*	*2.65*
Boomerang	1	2.03	2.28	3.32	2.55
	2	2.27	2.17	3.26	2.56
	3	2.12	2.27	3.35	2.58
Average		*2.14*	*2.24*	*3.31*	*2.56*
Giraf	1	2.05	2.54	3.29	2.62
	2	2.35	2.43	3.19	2.66
	3	1.75	2.26	3.27	2.43
Average		*2.05*	*2.41*	*3.25*	*2.57*
Asketa	1	2.25	2.54	3.42	2.74
	2	2.34	2.47	3.26	2.69
	3	2.15	2.44	3.36	2.65
Average		*2.25*	*2.48*	*3.35*	*2.69*
Gazeta	1	2.14	2.62	3.40	2.72
	2	2.28	2.52	3.37	2.72
	3	1.99	2,39	3.41	2.59
Average		*2.14*	*2.51*	*3.39*	*2.68*
Total average 1		2.15	2.38	3.21	2.58
Total average 2		2.34	2.29	3.16	2.59
Total average 3		2.15	2.28	3.23	2.55
Total average		*2.21*	*2.31*	*3.20*	*2.57*
$LSD_{0,05}$		A – 0.08 B - n.s	A – 0.10 B – 0.06	A - 0.08 B - n.s.	A – 0.09 B - n.s. C – 0.07
$LSD_{0,01}$		A – 0.11 B - n.s.	A – 0.13 B – 0.08	A – 0.10 B - n.s.	A – 0.12 B - n.s. C – 0.09

Table 5. Sugar yield (t ha^{-1}) u zavisnosti od hibrida, zaštite fungicidima i godine

Hybrid (A)	Variant (B)	Year (C)			*Average*
		2010	2011	2012	
Belinda	1	7.24	5.82	4.87	5.97
	2	9.89	8.13	6.30	8.16
	3	12.09	8.86	7.25	9.40
Average		*9.73*	*7.66*	*6.14*	*7.84*
Colonia KWS	1	9.98	9.85	6.50	8.78
	2	12.27	11.12	7.69	10.36
	3	14.13	12.68	8.07	11.62
Average		*12.13*	*11.21*	*7.42*	*10.25*
Elvis	1	5.87	7.45	3.99	5.77
	2	7.06	9.25	5.45	7.25
	3	7.82	9.65	5.89	7.79
Average		*6.92*	*8.79*	*5.11*	*6.94*
Sandor	1	8.04	8.11	5.32	7.16
	2	11.31	10.94	6.35	9.53
	3	14.21	11.11	7.32	10.88
Average		*11.19*	*10.05*	*6.33*	*9.19*
Boomerang	1	9.11	9.67	6.72	8.50
	2	12.19	10.94	7.91	10.35
	3	13.60	11.58	7.59	10.93
Average		*11.63*	*10.73*	*7.41*	*9.92*
Giraf	1	6.43	6.58	5.01	6.00
	2	8.75	9.43	6.81	8.33
	3	10.00	10.54	7.61	9.38
Average		*8.39*	*8.85*	*6.48*	*7.91*
Asketa	1	8.20	8.68	5.05	7.31
	2	9.72	10.45	6.33	8.83
	3	12.53	11.50	6.72	10.25
Average		*10.15*	*10.21*	*6.03*	*8.80*
Gazeta	1	6.60	7.09	4.70	6.00
	2	8.01	8.91	5.81	7.58
	3	13.37	9.57	6.57	9.84
Average		*9.20*	*8.52*	*5.69*	*7.81*
Total average 1		7.64	7.91	5.27	6.94
Total average 2		9.90	9.92	6.58	8.80
Total average 3		12.22	10.69	7.13	10.01
Total average		*9.92*	*9.50*	*6.33*	*8.58*
$LSD_{0,05}$		A – 0.55 B – 0.52	A – 0.25 B – 0.41	A - 0.62 B - 0.37	A – 0.54 B – 0.46 C – 0.39
$LSD_{0,01}$		A – 0.72 B – 0.68	A – 0.33 B – 0.54	A – 0.81 B – 0.49	A – 0.71 B – 0.60 C – 0.58

Significant impact on sugar yield had also fungicide apllication. Already one fungicide application resulted in sugar yield average increase by 1.86 t ha^{-1}, which in three fungicide applications increased the average by 3.06 t ha^{-1} compared to the control and by 1.21 t ha^{-1}

compared to variant 2. Because of leaf damages caused by *C. beticola* Sacc. sugar yield on the control was decreased by 21.14% compared to the variant with one fungicide application and by 30.67% compared to the variant with three fungicide applications. Higher losses due to disease development were expected during the humid year 2010 and smaller in the remaining two dry years.

The lowest sugar yield on treatments without fungicide application in three-years average was achieved with hybrids Elvis, Belinda, Gazeta and Giraf. The pure sugar yield increase with three fungicide applications was lowest with hybrid Elvis (2.0 t ha^{-1}), then Belinda and Giraf (3.4 t ha^{-1}) and highest with hybrid Gazete (3.8 t ha^{-1}), what shows that the effectiveness of fungicide application is not dependent on declared tolerance to *C. beticola* Sacc.

Analysis of Sugar Beet Leaf Damage Caused by the Attack of Cercospora beticola Sacc

The intensity of sugar beet leaf damage caused by *C. beticola* Sacc. depended on the number of fungicide applications, hybrid and year of research. In average, the sugar beet leaf damage, during all the three years of research, caused by *C. beticola* Sacc. was relatively high and ranged up to 2.67 (Table 6).

Table 6. Analysis of sugar beet leaf damage caused by the attack of *Cercospora beticola* Sacc

Hybrid (A)	Variant (B)	Year (C)			*Average*
		2010	2011	2012	
Belinda	1	4.75	4.25	4.15	4.38
	2	3.56	3.38	3.45	3.46
	3	1.75	1.42	1.12	1.43
Average		*3.35*	*3.02*	*2.91*	*3.09*
Colonia KWS	1	4.10	3.60	3.13	3.61
	2	2.70	2.50	2.63	2.61
	3	0.75	0.43	0.50	0.56
Average		*2.52*	*2.18*	*2.09*	*2.26*
Elvis	1	4.50	4.10	4.24	4.28
	2	3.84	3.10	3.25	3.40
	3	2.54	1.52	1.63	1.90
Average		*3.63*	*2.91*	*3.04*	*3.19*
Sandor	1	5.00	4.00	4.30	4.43
	2	3.10	3.13	3.10	3.11
	3	0.62	0.83	0.75	0.74
Average		*2.91*	*2.65*	*2.72*	*2.76*
Boomerang	1	4.75	4.23	4.00	4.33
	2	3.16	2.75	2.73	2.88
	3	1.10	0.86	1.10	1.02
Average		*3.00*	*2.61*	*2.61*	*2.74*
Giraf	1	5.00	4.25	4.35	4.53
	2	3.95	3.55	2.78	3.43
	3	2.75	1.33	1.50	1.86
Average		*3.90*	*3.04*	*2.88*	*3.27*

Hybrid (A)	Variant (B)	Year (C)			*Average*
		2010	2011	2012	
Asketa	1	3.90	3.45	3.35	3.57
	2	2.54	2.25	2.30	2.36
	3	0.53	0.45	0.35	0.44
Average		*2.32*	*2.05*	*2.00*	*2.12*
Gazeta	1	3.75	3.50	3.25	3.50
	2	2.75	2.34	2.00	2.36
	3	0.50	0.28	0.53	0.44
Average		*2.33*	*2.04*	*1.93*	*2.10*
Total average 1		4.47	3.92	3.84	4.08
Total average 2		3.20	2.88	2.78	2.95
Total average 3		1.15	0.89	0.94	0.99
Total average		*2.94*	*2.56*	*2.52*	*2.67*
$LSD_{0,05}$		A – 0.43 B – 0.42	A- 0.41 B- 0.33	A - 0.49 B - 0.27	A – 0.47 B – 0.46 C – 0.28
$LSD_{0,01}$		A – 0.56 B – 0.55	A – 0.54 B – 0.43	A – 0.64 B – 0.36	A – 0.62 B – 0.60 C – 0.37

The highest leaf damages were during the humid year 2010 with an average grade for all hybrids and treatments of about 2.94. In 2010 the average grade on the variant without fungicide application was 4.47 and 1.15 on the variant with three fungicide applications. The grades on variant 1 ranged in that year from 3.75 (hybrid Gazeta) to 5.0 (hybrids Giraf and Sandor), to 4.75 (non tolerant hybrid Belinda) respectively. At the same time, grades on variant 3 ranged from 0.50 (hybrid Gazeta) to 2.75 (hybrid Giraf), while the grade of sensitive hybrid Belinda was below 1.75. Already these data show the insufficient tolerance of today's hybrids to sugar beet leaf disease caused by *Cercospora beticola* Sacc. in climates with warm and humid summers and the incorrect labeling of tolerance which cannot be accepted in practice. The lowest leaf damages were achieved in dry 2012 with an average grade of 2.52 in a range from 3.13 (Colonia KWS) to 4.35 (Giraf) on the variant without fungicide application and in range from 0.35 (Asketa) to 1.63 (Elvis) on the variant with three fungicide applications.

Within the research, hybrid Giraf was the most sensitive hybrid to leaf disease caused by *C. beticola* Sacc., whereby hybrids Gazeta and Asketa showed significantly higher tolarance compared to other hybrids. However, the tolerance of these hybrids is still insufficient under such weather conditions, so the application of fungicides in sugar beet production is still an obligatory measure. Furthermore, achieved results show that the declared tolerance of hybrids is not accurate which is proved by the fact that hybrid Belinda, as the only sensitive hybrid, did not show more leaf damages compared to some hybrids declared as tolerant.

DISCUSSION

Weather conditions during vegetation have considerable effects on the growth and development of sugar beets, but also on infections, incubation period and sporulation of

fungus *Cercospora beticola* Sacc., as well as the level of damages caused by. According to a conducted research, the mean root yield and sugar yield, as well as the sugar content and the sugar in molasses was significantly depended on weather characteristics during the growing season. Root yield and sugar yield ranged from 51.15 t ha^{-1} and 6.33 t ha^{-1}, respectively, in 2012 to 83.67 t ha^{-1} and 9.92 t ha^{-1}, respectively, in 2010. At the same time sugar content during the dry year was 15.52% followed by higher sugar in molasses of about 3.32%, while during the wet year best production results were achieved. This year also provided favorable conditions for the development of disease, so in 2010 were registered the greatest damage, in which fungicide application recorded the highest increase of analyzed production results. Obtained results about the impact of weather characteristics on achieved root and pure sugar yield, as well as on the root quality are in line with the results registered by Pospišil et al. (2006), Kristek et al. (2006) and Kristek et al. (2013).

Realization of increasing root yield and root quality of sugar beet is constantly a desire and an effort of sugar beet producers. That is why they launch numerous measures to improve the production, among them, one of the most important measures is to preserve leaf health in order to reduce leaf restoring processes and to keep photosynthesis processes as high as possible. The impact of leaf preserve by fungicide applications is given by the achieved results. On the treatment without fungicide application the lowest results were achieved, so the mean root yield was 61.21 t ha^{-1}, mean sugar content was 13.92% and mean sugar yield was 6.94 t ha^{-1}. One fungicide application increases the root yield by 8.7 t ha^{-1} (14.22%), sugar content by 1.27% (relative 9.13%) and sugar yield by 1.86 t ha^{-1} (26.84%), whereas three fungicide applications increases root yield by 15.92 t ha^{-1} (26.01%), sugar content by 1.61% (relative 11.57%) and sugar yield by 3.07 t ha^{-1} (44.24%). In a two years research included two locations and one fungicide application Rešić (2003) achieved, in the first year of research, an increase of root yield by 8.02 t ha^{-1} (15.79%) compared to the control, with two fungicide applications the increase was even higher by 12.74 t ha^{-1} (24.50%). At the same time with one and two fungicide applications the sugar content was increased by 0.40% (relative 2.85%) and 0.74% (relative 5.29%) respectively. Sugar yield was increased by 1.33 t ha^{-1} (18.32%) with one fungicide application and by 2.16 t ha^{-1} (29.85%) with two fungicide applications. In the second year of research one fungicide application increased root yield by 6.40 t ha^{-1} (16.26%), sugar content by 1.35% (relative 10.55%) and sugar yield by 1.33 t ha^{-1} (18.32%), which in the increase with two fungicide applications was by 7.81 t ha^{-1} (19.94%), 1.83% (relative 14.30%) and 1.12 t ha^{-1} (21.52%). In a similar research with 26 sugar beet hybrids Kristek et al. (2006) achieved, in treatment with fungicides application compared to the control, an increase of root yield by 11.07 t ha^{-1} (14.08%), sugar content by 1,00% (relative 7,1%) and sugar yield by 2.08 t ha^{-1} (23.00%). Glavaš-Tokić (2009) reported that with one fungicide application the sugar yield was increased by 1.01 t ha^{-1} (10.8%) compared to the control and with two fungicide applications by 1.84 t ha^{-1} (19.6%), as well as fungicide efficiency depended on genotype. In sensitive hybrids with one fungicide application the sugar yield was increased by 1.30 t ha^{-1} (15.5%) and with two fungicide applications by 2.33 t ha^{-1} (29.5%). Application of fungicides is necessary in Croatia as concluded Kristek et al. (2008) after a three years research with 23 sugar beet hybrids in conditions of natural infection with and without fungicide applications. On treatment without fungicide application, because of leaf damages, compared to treatment with fungicide application and preserved leaves the decrease was by 11.5 t ha^{-1} (13.0%) for root yield, 1.35% (relative 8.4%) for sugar content and 2.5 t ha^{-1} (20.3%) for sugar yield. In favorable year for disease development

losses in production were even higher, so root yield was lower for 15 t ha^{-1}, sugar content for 1.88% and sugar yield for 3.72 t ha^{-1}. Also with other hybrids similar results were achieved in this research where the largest decrease was in 2010. In a two year field trial on two locations Kristek et al. (2006) reported a visual rating of leaf damages caused by *C. beticola* in a scale from 0-5, for all hybrids on treatment without fungicides application the grade was 3.17 and for the hybrids on treatment with fungicides application the grade was only 1.53. Three hybrids showed higher tolerance: Canaria, Palma and Europe. Within the research the average grade for all hybrids in condition without use of fungicide was 4.08, in conditions with one fungicide application the average grade was 2.95 and in conditions with three applications the average grade was 0.99. Significantly higher tolerance compared to other hybrids showed Gazeta, Asketa and Colonia KWS, while most sensitive showed to be Giraf, Elvis and Belinda. According to sugar yield significantly better, compared to other hybrids, were Colonia KWS and Boomerang. Kristek et al. (2011) achieved the highest sugar yield using the hybrids Gazeta, Merak and Severina.

CONCLUSION

Based on the three-year research production values of 8 sugar beet hybrids grown on eutric brown soil in eastern Croatia under conditions of natural infection by pathogenic fungus *Cercospora beticola* Sacc. in variants with and without fungicide application, the following can be concluded:

- Root yield, sugar content and sugar yield as well as leaf damages depended on the number of fungicide treatments, hybrids and weather conditions during the growing season;
- On variant without fungicide application (1) lower root yield of about 8.7 t ha^{-1} (12.45%) was achieved, sugar content was lower for 1.27% (relative 8.36%) and sugar yield was lower for 1.86 t ha^{-1} (21.14%) compared to variant with one fungicide application (2). Compared to variant with three fungicide applications (3) root yield was lower for 15.92 t ha^{-1} (20.64%), sugar content was lower for 1.61% (relative 10.37) and sugar content was lower for 3.07 t ha^{-1} (30.67%);
- In 2010, when we had favourable weather conditions for plant growth but also for leaf disease attack (warm and humid summer), best production results were achieved, but also greatest decrease in root yield, pure sugar yield and sugar beet quality was recorded on variant without funigicide application;
- Hybrids in research differed among themselves, but the impact of hybrids on production values is less than the impact of fungicide application. During the research, highest root yields were achieved with hybrids Boomerang, Colonia KWS and Sandor. The highest sugar content were found in Colonia KWS, Asketa and Boomerang. The lowest content of sugar in molasses had hybrid Colonia KWS. According to pure sugar yield hybrids Colonia KWS and Boomerang were better then the others;

- The highest tolerance to leaf spot disease caused by *Cercospora beticola* Sacc. with a minimum average grade of leaf damages have shown hybrids Gazeta, Asketa and Colonia KWS.
- Damage because of omitted fungicide applications were highly significant for all hybrids, so the regular fungicide application against *C. beticola* Sacc., in these climates, it is still obliged and very cost effective measure in sugar beet production.

REFERENCES

[1] Biancardi, E., Colombo, M., De Biaggi, M., Ghedini, R., Stevanato, P. (2001.): Protektive, Curative and eradikant aktivity of the Strobilurin fungicide Azoxystrobin against *C. beticola* and Erisiphe betae. *Journal of Phytopathology* 151 (11-12): 647-651.

[2] Buchholz, K., Märländer, B., Puke, H., Glattkowski, H., Thielecke, K. (1995.): Neubewertung des technischen Wertes von Zuckerrüben. *Zuckerindustrie* 120:113–121.

[3] Glavaš-Tokić, R.(2009.): Utjecaj genotipa, mikroflore tla i zaštite od parazitne gljive Cercospora brticola Sacc. na elemente prinosa i kvalitete šećerne repe. Master of Science Thesis. University of J. J. Strossmayer. Faculty of Agriculture in Osijek.

[4] Hoffman, G. M., Schmutterer, H. (1999.): Parasitäre Krankheiten und Schädlinge an landwirtschaftlichen Nutzpflantzen. *Verlag Eugen Ulmer*, 657:384-391.

[5] Kristek, A., Glavaš-Tokić, R., Kristek, S., Antunović, M. (2006.): Značaj izbora sorte i primjene fungicida u sprječavanju pjegavosti lišća šećerne repe *Cercospora beticola* Sacc. i ostvarivanju visokih prinosa kvalitetnog korijena. *Poljoprivreda*, 12 (1): 27-34.

[6] Kristek, A., Glavaš-Tokić, R., Kristek, S., Antunović, M. (2008.): Utjecaj oštećenja lišća šećerene repe u vegetaciji na prinos i kvalitetu korijena. Zbornik radova sa 43. hrvatskog i 3. međunarodnog simpozija agronoma. Pospišil, M. (ur.). Zagreb. Agronomski fakultet Sveučilišta u Zagrebu, *Opatija*, 18.-21. 02. 2008. 641- 645.

[7] Kristek, A., Kristek, S., Glavaš-Tokić, R, Antunović, M., Rašić,S.,Rešić,I., Varga, I. (2013.): Prinos i kvaliteta korijena istraživanih hibrida. Poljoprivreda, 19 (1): 33-40.

[8] Pospišil, M., Pospišil, A., Mustapić, Z., Butorac, J., Tot, I., Žeravica, A. (2006.): Proizvodne vrijednosti istraživanih hibrida šećerne repe. Poljoprivreda, 12 (1): 16-21.

[9] Rešić, I. (2003.): Djelotvornost fungicida i tolerantnost sorata šećerne repe na gljivu *Cercospora beticola* Sacc. Master of Science Thesis. University of J. J. Strossmayer. Faculty of Agriculture in Osijek.

[10] Ruppel.,E.G., (1995.): Cercospora leaf spot. U Compendium of Beet Diseases and Insects, ed. By Whitnej, E.D., Duffus, E.J., APS Press, 8-9.

[11] Sharifi, Hamid; Urazi Zade, Mohammad Reza; Hossein Pour, Mostafa; Abdollahian Nuqabi, Mohammad; Bbaba`i, Babak; Mansouri; Mandani, Hassan (2005): Effects of cercospora leaf spot on the yield losses of sugar beet lines varied in disease resistance in Dezful area. Agricultural Scientific Information and Documentation Centre, Agricultural Research and Education Organization (Iran (Islamic Republic of)) ASIDC Yaman Avenue, Chamran Highway, P.O. Box 19835-111. Tehran.

[12] Sharifi, Hamid; Gaforzadeh dabagh,; Mandani, H.; Reza ghareb, M.; Abdollahian Noghabi, M.; Babaee, B. (2007): effect of planting date,sugar beet cultivar and

frequency of fungicide application on leaf spot of sugar beet at safi abad agricultural research center Dezful _Iran . Agricultural Scientific Information and Documentation Centre, Agricultural Research and Education Organization (Iran (Islamic Republic of)) ASIDC. Yaman Avenue, Chamran Highway, P.O. Box 19835-111. Tehran.

[13] Smith, G.A.,Gaskill, J.O. (1970.): Inheritance of Resistance to Cescospora Leaf Spot in Sugarbeet. *J. Am. Sugar Beet Technol*. 16: 172-180.

[14] Wolf, P.F.J., Weiss, F. J. (1995.): Principles of an integrated pest menagemend of *Carcospora beticola* (Sacc.) in sugar beets. *Journal of plant disease and protection* 102 (6): 578-592.

[15] Wolf, P.F.J., Kraft,R., Verreeti, J.A. (1998.): Characteristics of damage caused by *Carcospora beticola* (Sacc.) in sugar beet as a base of yield loss forecast. *Journal of plant disease and protection* 105(5): 462-474.

[16] Yoshimura, Y.,,Abe, H., Ohtuschi, K. (1992.): Varietal Difference in the Susceptibility to Cercospora Leaf Spots and its Effect on Quality of Sugar Beets. *Proc. Japan soc. Sugar Beet Tehnol.* 34: 112-116.

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