The effect of a fungicide application on the yield and quality of barley grain and malt

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ABSTRACT

In small-plot field trials conducted in 2000–2002 we studied the effect of fungicides on the yield and selected technological parameters of grain of malt barley and on malt. For the treatment we used Cerelux (active ingredients: fenpropimorph, flusilazole), Amistar (azoxystrobin) and Caramba (metconazole) applied in two stages of stand development (DC 47 and 55). Compared to the untreated control plants the yield grains ranged between 6.9 and 16.5% after the application of fungicides. The application of fungicides increased the proportion of full grains and had a favourable effect on the chemical composition of grain. After the treatment with azoxystrobin the content of N-substances decreased from 11.43 to 11.07% as compared to the controls. The highest starch content of grain was observed after the application of the active ingredient metconazole; the average content ranged between 64.44 and 64.62%. Compared to the controls the highest relative yield of malt starch (124.2–125.2%) was achieved after the application of azoxystrobin or a combination of azoxystrobin and metconazole in the DC 47 stage. The highest average attainable degree of fermentation was 78.57% and was discovered in the untreated control.

Keywords: malt barley; malt; fungicide; yields; grain quality

The major part of production of malt barley grain is used to feed farm animals. The minor part is used in the food industry, primarily as a raw material for the production of malt and subsequently of beer (Špunarová and Prokeš 1998). To achieve the corresponding grain yields in the required malting quality frequently poses considerable problems. According to Flašarová and Onderka (1997) the yields are dependent on the production potential and capability of accumulating assimilates in interaction with the soil and weather conditions. The yields and the yield quality are largely influenced also by the cultural practices, an integral part of which are also interventions related to stand protection, not only against weeds and pests, but also against diseases. Tvarůžek et al. (1996) stated that integrated protection of cereals against diseases is primarily based on the variety and its genetically established resistance. As an example we can take the resistance of some barley varieties against mildew. But even these varieties cannot do without the protection of fungicides. Kubinec (1998) has it that the application of fungicides during vegetation can significantly contribute to the formation of grain yields and to yield quality. The result of the negative effect of fungous diseases on yields is seen, in particular, in the reduction of the photosynthetic active leaf area; this again limits the production of assimilates deposited in the grain. However, Prokinová (1999) observed more danger associated with the appearance of necroses and pigmentation of tissues directly on the caryopsis, which are due to the attack by micromycetes. Sing et al. (1991), among other authors, is of the opinion that the presence of some fungi species may impair the germinating capacity of the caryopses by producing phytotoxical substances; for the further use of barley grain, however, this is inadmissible. The production of mycotoxins, that are transferred into the final product and may affect health of consumers, is also dangerous.

MATERIAL AND METHODS

The Kompakt malt barley variety was grown on small plots in a field trial established in the agricultural co-operative, Agrospol Velká Bystřice, in 2000–2002. The agrochemical properties of the plots on which the experiments were conducted in individual years are given in Table 1. Figures 1–2 show the weather conditions in the respective years.

Table 1. Agrochemical soil properties before the establishment of the experiment, depth 0–30 cm

Year	pH/KCl	Available nutrients – Mehlich III (mg/kg)			
		P	K	Ca	Mg
2000	6.57	81.9	150	2020	96
2001	7.10	136	244	4050	291
2002	6.2	132	217	2250	142

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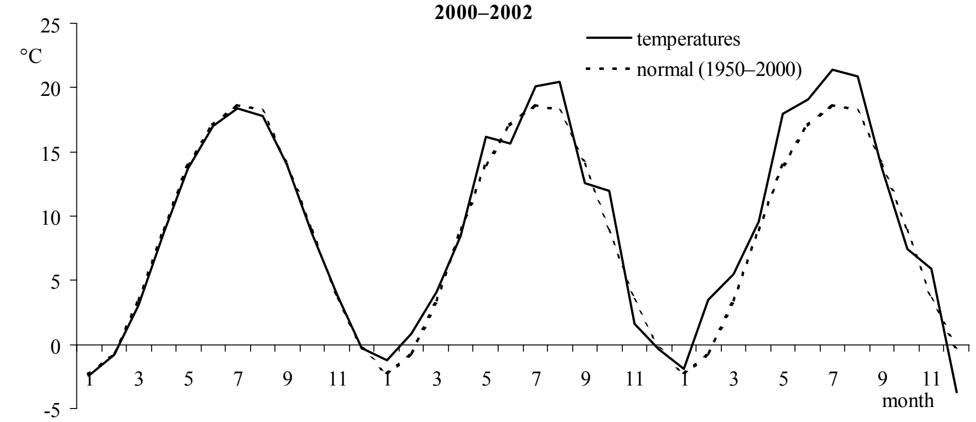

Figure 1. Temperatures in 2000–2002

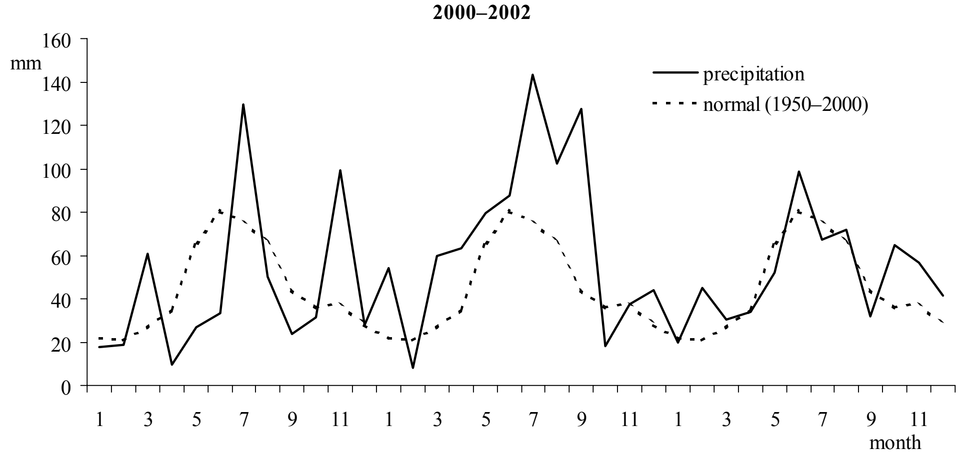

Figure 2. Precipitation in 2000–2002

In all the experimental years the barley was grown after sugar beet as the preceding crop. The plot was mean-ploughed in the autumn and the sugar beet tops were ploughed in. Prior to sowing phosphoric fertilizers (100 kg of Amofos/ha) were applied to rectify the unfavourable P/C ratio of the tops. Since the post-harvest residues contained a large amount of nutrients, no further fertilization was performed. Sowing was conducted directly into ploughed soil with the Amazone seeding machine equipped with rotary harrows. The date of sowing and the seeding amount are given in Table 2.

In the course of vegetation the barley stand was treated with fungicides. Since the attack of diseases on this barley variety does not appear in a standard manner until the later stages of development we chose two dates for the treatment (DC 47 and DC 55). The preparations used for the treatment were: Cerelux Plus, Amistar, Caramba and selected combinations of these preparations. The variants included in the trial are shown in Table 3. The fungicide was applied with a knapsack sprayer; the standard pressure was 0.3 MPa in 300 l/ha of water. The variants were repeated 4 times and the area of one replicate was 20 m^2.

Prior to fungicide application, the disease infestation of the stand was evaluated. At the time of spraying the flag leaf was healthy. The results are given in Table 4.

The plants were harvested with a small-plot harvester in the stage of full maturity. After the harvest the grain yields from each replication were determined and sampled for evaluations of mechanical grain quality. Within the framework of these tests we determined the share of grain above the 2.8 and 2.5 mm sieve (Steinecker's sieve). In the composite samples we evaluated the starch content (according to Ewers) and proteins (according to Kjeldahl). At the Brewery and Malting Research Institute in Brno we performed micro-malting and we determined the achievable degree of fermentation (Basařová et al. 1992). The yield results were statistically processed by variance analysis and then tested according to Tukey on the significance level of 95% and interpreted using confidence intervals of the UNISTAT 5.1 programme.

Table 2. The date of sowing and the seeding amount

Year	Date of sowing	Seeding amount (in MGS)
2000	10.3.	3.7
2001	7.4.	4.1
2002	14.3.	3.8

MGS = million germinating seeds

Table 3. Layout of trial

Variant/preparation	Stage of growth at application	Dose (l/ha)	Amount of active ingredient per hectare
1) control			
2) Cerelux Plus	DC 47	0.8	fenpropimorph 300 g/l, flusilazole 128 g/l
3) Amistar	DC 47	0.8	azoxystrobin 200 g/l
4) Amistar	DC 55	0.8	azoxystrobin 200 g/l
5) Caramba	DC 47	1.2	metconazole 72 g/l
6) Caramba	DC 55	1.2	metconazole 72 g/l
7) Caramba + Amistar	DC 47	0.6 + 0.4	metconazole 36 g/l + azoxystrobin 100 g/l
8) Caramba + Amistar	DC 55	0.6 + 0.4	metconazole 36 g/l + azoxystrobin 100 g/l

Table 4. Health condition of the leaf area prior to fungicide application

Year	% of infestation			
	Erysiphe graminis		*Puccinia hordei*	
	F1	F2	F1	F2
2000	0	5	0	1
2001	1.0	1–5	0	0
2002	1–5	5–10	0	0

F1, F2 – the 1st and 2nd leaves below the flag leaf

RESULTS AND DISCUSSION

In 2000 the fungicide treatment considerably influenced the yields of barley grain. The significantly highest yields, compared to the controls, were observed after the application of Amistar and Caramba in the DC 47 stage of development (Figure 3). After the application of both fungicides the yield grains were higher than 10%. The combination of Caramba and Amistar was also relatively positive; irrespective of the date of application the average yields increased by ca 8%. The date of the application in the given year had a more marked positive effect on yields if the preparation was applied earlier; this holds good for a variant where single applications of fungicides with strobilurin as the active ingredient were used and also for preparations containing metconzale. The yield gains ranging around ca 10% correspond with data presented by Kubinec (1998) who achieved similar results in barley varieties Jubilant and Garant. Nevertheless, when we evaluate the effect of the fungicides we must keep in mind the weather conditions, which were not very favourable for the development of diseases in the experimental year. The considerable deficit in precipitation (Figure 2) was markedly reflected in the relatively weak pressure of the diseases and accelerated vegetation, having a negative effect on yields and in this way also reflected in the differences between the individual fungicide variants. In Figures 4 and 5 we can see that, to some extent, the share of the respective grain fractions participated in the differences in grain yields determined in the individual variants. In terms of the overall evaluations the proportion of grain over the 2.8 mm sieve (79.8%) was the lowest in the control variant; the best values were observed after the application of strobilurin as the active ingredient at a later date.

In 2001 the grain yields were considerably higher (Figure 6) and the effect of all fungicides was significantly positive, which was due to the considerably better weather conditions. Petr et al. (1987 – cit. Flašarová and Onderka 1997) drew attention to the fact that a sufficient sum of precipitation during all the stages of development that are of key importance for yield formation, as well as

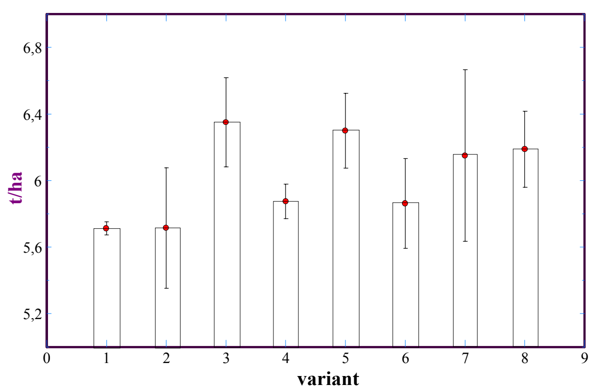

Figure 3. Yields of barley grain in 2000

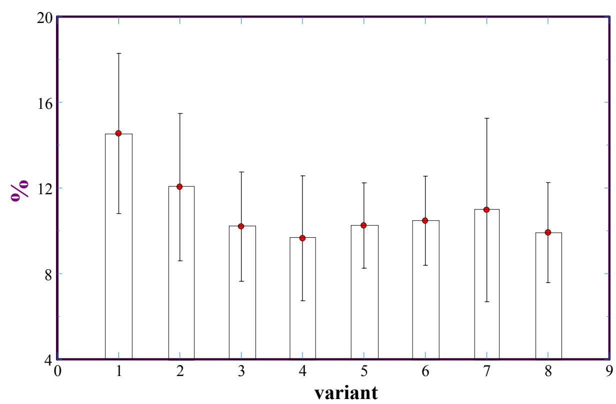

Figure 4. The proportion of grain on the 2.5 mm sieve (2000)

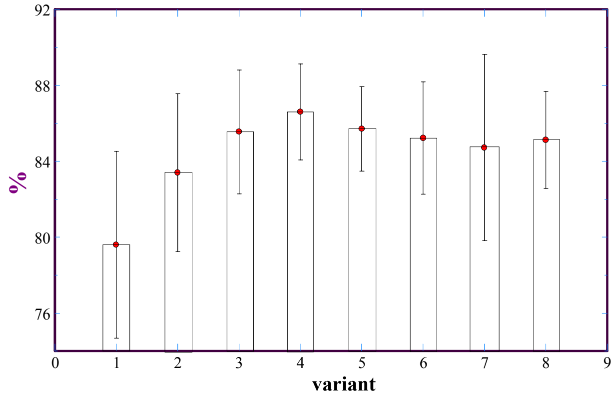

Figure 5. The proportion of grain on the 2.8 mm sieve (2000)

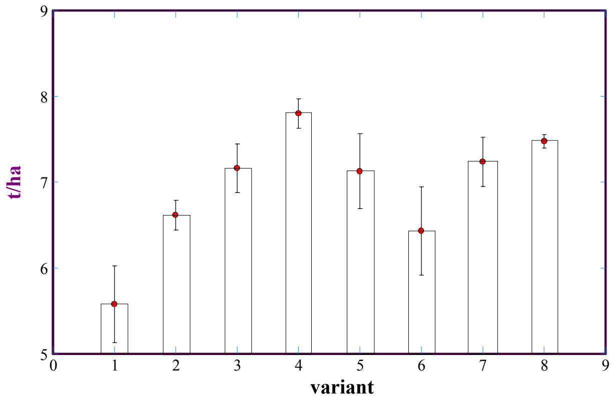

Figure 6. Yields of barley grain in 2001

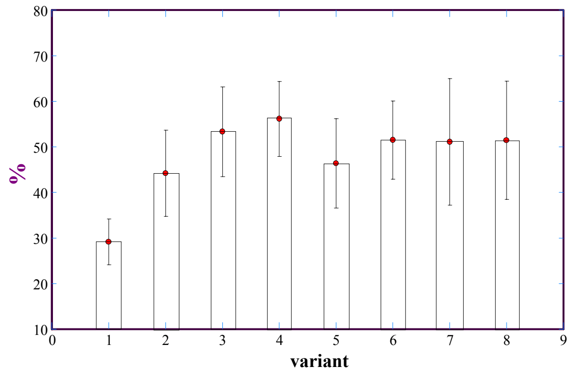

Figure 7. The proportion of grain on the 2.5 mm sieve (2001)

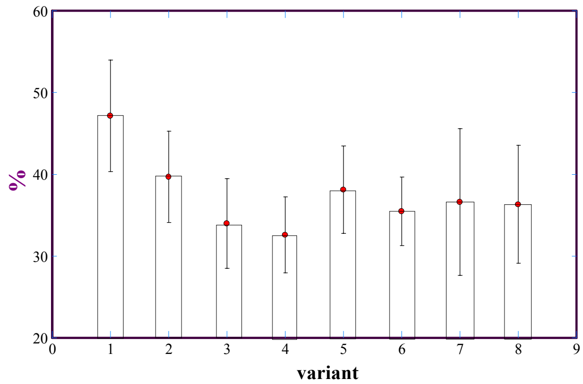

Figure 8. The proportion of grain on the 2.8 mm sieve (2001)

favourable temperatures, had a positive effect on the potential productivity of the ear (Figure 1). On top of that, the conditions for development of diseases, particularly diseases of the ear, were favourable and considerably reduced yields in the control variant. The significantly highest grain yields were monitored in the variant where strobilurin (7.79 t/ha) was applied at a later date. The yields of this variant were by 39.8% higher than yields of the untreated control variant. The yields of the variants where strobilurin as the active ingredient was applied were positively influenced only when applied at a later date (variants 4 and 8), while the active ingredient metconazole in the Caramba fungicide had a better effect when applied at an earlier date. The higher grain yields in variants treated with fungicides were to some extent due to the higher proportion of the front grain. Although most of the grain on the 2.8 mm sieve was found in the control variant (Figure 8), compared to the other variants the proportion of grain over the 2.5 mm sieve (Figure 7) was significantly lower; this was found to be decisive in the total sum of both proportions expressing the basic parameter of barley quality. While the proportion of grain on the 2.5 mm sieve in the control variant was only 76.3%, in the other variants it ranged above 83.9%, and was the

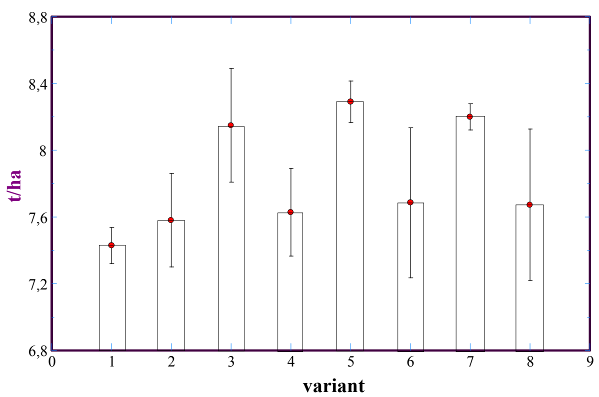

Figure 9. Yields of barley grain in 2002

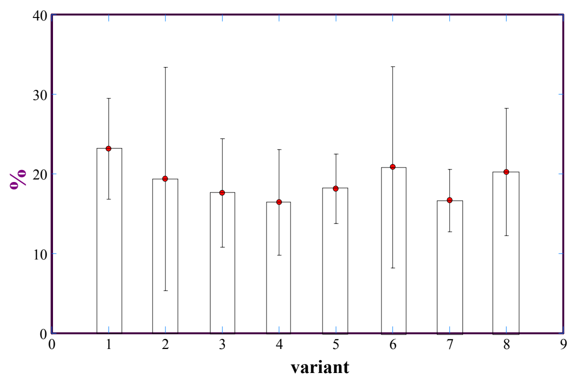

Figure 10. The proportion of grain on the 2.5 mm sieve (2002)

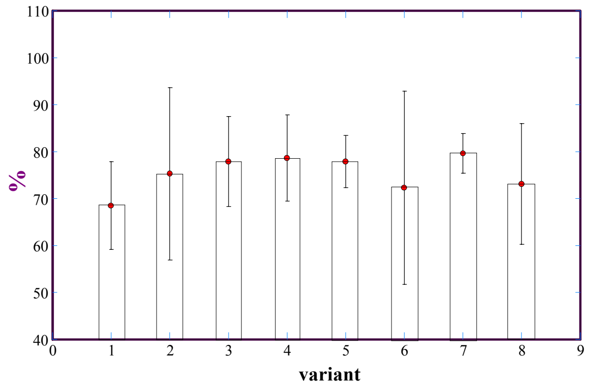

Figure 11. The proportion of grain on the 2.8 mm sieve (2002)

highest in variant 4 where also the yields were the highest (88.7%). The better health condition of the plants contributed to grain production later on, it supported starch production and we can assume that it also created better conditions (Przulj and Momčilović 2001) for the transfer of assimilates from the vegetative parts of the plant into the grain.

While no definite differences among the respective dates of application in the previous years were observed, and it was the type of the fungicide that had a greater effect, in 2002 due to the early onset of diseases the early date of application was significantly positive (Figure 9), i.e. of preparations containing both the active ingredient azoxystrobin and metconazole, and/or the combination of the two. The differences between early and late treatment ranged between 0.52 and 0.60 t/ha. The late applications increased the yields compared to the untreated control by only 0.199–0.257 t/ha. Also in this year a low proportion of grain on the 2.8 mm sieve was determined in the control variant (Figure 11) and a slightly higher proportion on the 2.5 mm sieve compared to the fungicide variants (Figure 10).

The chemical composition of the grain differed considerably in the respective years. The highest differences were in the content of protein. The year 2000 was the least favourable; the content of protein was on average 11.68%. A high level of N-substances was monitored also in 2002; on the contrary the favourable conditions of 2001 contributed to the relatively very low level of nitrogenous substances (Table 5). The high level of starch

Table 5. Selected technological parameters of barley grain and malt

Variant	2000			2001			2002			Average 2000–2002		
	N-substances	starch	DSP	N-substances	starch	DSP	N-substances	starch	DSP	N-substances	starch	DSP
1	11.8	63.16	78.4	10.6	64.4	79.7	11.9	63.9	77.6	11.43	63.82	78.57
2	11.8	62.7	76.7	10.3	64.5	79.2	11.4	63.4	77.7	11.17	63.53	77.87
3	11.3	65.25	76.2	10.4	64.1	79.1	11.5	63.7	77.2	11.07	64.35	77.50
4	11.5	63.35	76.5	10.4	64.8	78.7	11.3	63.7	77.6	11.07	63.95	77.60
5	11.8	64.53	76.8	10.2	65	79.3	11.5	63.8	76.9	11.17	64.44	77.67
6	11.8	64.06	78.1	10.3	66.4	79.3	11.3	63.4	76.6	11.13	64.62	78.00
7	11.5	63.61	77.5	10.3	64.9	79.8	11.4	63.8	78	11.07	64.10	78.43
8	11.9	63.24	77.9	10.2	65.2	79.1	11.6	63	78.4	11.23	63.81	78.47
Average	11.68	63.74	77.26	10.34	64.91	79.28	11.49	63.59	77.5	11.17	64.08	78.01

DSP – attainable degree of fermentation

Table 6. Amount of malting starch

Variant	2000		2001		2002		Average 2000–2002	
	t/ha	rel. %	t/ha	rel. %	t/ha	rel. %	t/ha	rel. %
1	2.663	100	2.186	100	3.376	100	2.742	100.0
2	2.623	98.5	2.837	129.8	3.535	104.7	2.998	111.0
3	3.023	113.5	3.17	145	3.852	114.1	3.348	124.2
4	2.74	102.9	3.529	161.4	3.59	106.3	3.286	123.5
5	2.996	112.5	3.104	142	3.905	115.7	3.335	123.4
6	2.807	105.4	2.945	134.7	3.477	103	3.076	114.4
7	2.901	108.9	3.286	150.3	3.929	116.4	3.372	125.2
8	2.898	108.8	3.384	154.8	3.537	104.8	3.273	122.8
Average	2.831		3.055		3.65		3.179	

(64.91%) in 2001 corresponded with the low content of proteins. The positive fact is that in the majority of cases the fungicide applications contributed to a lower level of N-substances in the grain. After the treatment with strobilurin over the period of 3 years the average content of proteins was the lowest and compared to the untreated control variant it decreased by 0.36%.

From the malting and brewery point of view it is important to determine the amount of malt starch obtained from one hectare, which is dependent on the yields of front grain and starch content in the caryopsis and the attainable degree of fermentation. Priority is given to the starch content, which is decisive for the amount of the extract in the malt and, consequently, the amount of produced beer. From this point of view, 2002 was the most satisfactory year, when the production of malt starch was the highest (Table 6). However, we must point out that it was mostly due to the yields. The greatest differences between the individual variants were observed in 2001 when the increase in the starch content, compared to the control variant, ranged between 29.8 and 61.4%; the yields were the highest after the application of strobilurins and of their combinations with the active ingredient metconazole.

From the presented results it unequivocally follows that it is necessary to perform targeted fungicide treatment during vegetation and that various types of fungicides should be available. The application must be timely, and the strobilurin-based fungicides should be applied rather as preventive measures. Not only the fungicidal protection contributes to higher yields, but it also influences considerably the quality of barley grain.

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ABSTRAKT

Vliv aplikace fungicidů na výnos a kvalitu zrna ječmene a sladu

V maloparcelkových polních pokusech byl v letech 2000–2002 ověřován vliv účinku fungicidů na výnos a vybrané technologické parametry zrna sladovnického ječmene a sladu. K ošetření byly použity přípravky Cerelux Plus (účinná látka fenpropimorph, flusilazole), Amistar (azoxystrobin) a Caramba (metconazole). Aplikace probíhala ve dvou fázích vývoje porostu (DC 47 a DC 55). Přírůstek výnosu po aplikaci fungicidů za sledované období se pohyboval oproti neošetřené kontrole v rozmezí 6,9–16,5 %. Aplikace fungicidů zvyšovala podíl plných zrn. Příznivě bylo ovlivněno i chemické složení zrna. Obsah N-látek se oproti kontrole snižoval z 11,43 na 11,07 % u varianty ošetřené azoxystrobinem. Nejvyšší škrobnatost zrna byla zaznamenána po aplikaci účinné látky metconazole a v průměru let se pohybovala na úrovni 64,44–64,62 %. Nejvyšší relativní výtěžnost sladařsky využitelného škrobu (124,2–125,2 %) v porovnání s kontrolou byla dosažena po aplikaci azoxystrobinu nebo kombinací azoxystrobinu s metconazole ve fázi DC 47. V průměru nejvyšší dosažitelný stupeň prokvašení 78,57 % byl pozorován u neošetřené kontroly.

Klíčová slova: sladovnický ječmen; slad; fungicid; výnos; kvalita zrna

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