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Evaluation of maize hybrids types harvested at the similar stage of maturity

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ABSTRACT

The objective of the experiments was to compare types of maize hybrids harvested at the similar stage of maturity, between one and two thirds of the milk line stage of grain. The study involved 9 hybrids with different parameters that were grown during a period of three subsequent years in two locations with different level of precipitation. Differences in terms of the content of dry matter between the hybrids at different timing of harvests were small (323 ± 22 g/kg), showing no statistical significance ($P = 0.34$). Comparing the early maturity hybrids with the medium early hybrids ($P < 0.05$), the former showed a lower content of starch (299 g/kg dry matter (DM)), and the latter showed a slightly higher value (312 g/kg DM) – while the measured proportion of neutral detergent fibre (NDF) among these two hybrids was 453 vs. 428 g/kg DM. Comparing the measured value of the normally ripening hybrids against the stay-green hybrids, the starch was 314 vs. 294 g/kg DM, and NDF was 434 vs. 451 g/kg DM, respectively. As for the comparison between the flint (vitreous) type of grain endosperm vs. dent (floury), measured value of the starch was 298 vs. 323 g/kg DM, and NDF was 451 vs. 427 g/kg DM, respectively.

Keywords: type of plant; earliness; *Zea mays*; precipitation; silage; FAO index

The agricultural practice requires more detailed and accurate research data and information. For farmers, the right choice of a proper maize hybrid has a decisive importance. The properties of the hybrids differ above all depending on the earliness, the type of the plant (stay-green vs. normal ripening), the type of the grain (flint vs. dent) or the type of the recommended usage (silage making vs. grain production) as well as by their intertypes. However, under practical conditions, some properties of the hybrids as declared by their sellers are not manifested.

The effects of the type of maize hybrids and their maturity stage on their yields and nutritional characteristics were presented by several authors, e.g. by Pilipavicius and Mikulioniene (2010) or Hetta et al. (2012). Cone et al. (2008) demonstrated that not only yields and nutritional parameters, but also the degree and the rate of *in vitro* rumen fermentation were significantly influenced by the growth stage and the content of dry matter (DM) in the entire plants at the moment of their harvest. For the same type of hybrid (i.e. stay-green) the stage of maturity of grain and the whole plant DM is closely related. When comparing with each other the different types of hybrids (e.g. stay-green and dry down), this relationship may be different. Differences in DM content, nutrients and digestibility are also given by proportion grain (ear) to the other parts of the plant. According to Ettle and Schwarz (2003), the constituents of the ear (dehusked) and residual plants are affected by maturity stage but not by type of hybrid.

However, if the hybrids showed a different degree of earliness on the day of the harvesting, they may be considered to be at different stages of maturity showing different contents of DM. This fact could be the reason why the declared properties

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of hybrids were not manifested (or functioning) at the moment of their comparison.

So, the objectives of the experiments are to compare the content of DM, the content of starch, the proportion of neutral detergent fibre (NDF), and the grain production starch among the different types of maize hybrids harvested at the similar stage of maturity, i.e. between one and two thirds of the milk line stage of grain.

MATERIAL AND METHODS

Altogether 9 maize hybrids (*Zea mays* L.) belonging to the FAO maturity class 230–320 were tested. Their characteristics are presented in Table 1. Experimental hybrids were chosen with regard to their earliness (early ones with FAO class ≤ 260 and early to medium ones with FAO class > 260), the type of ripening (stay-green and normal ripening), the type of grain endosperm (flint or dent) and the type of the producer's recommendation of usage (either for silage making or for production of grain).

Within a period of three years, the hybrids were grown in two locations, Troubsko (49°17'27''N, 16°49'81'E) and Prague-Uhříněves (50°03'65''N, 14°60'90''E). The distance between them is about 200 km and both are situated in sugar-beat-growing region. Their altitude is about 280 m a.s.l. and in both locations the soil on the experimental fields was classified as loamy to clayey-loamy with a neutral soil reaction.

In both locations, the hybrids were sown on approximately identical dates. The experiment was established in randomised blocks with three replicates per hybrid, and the crop density was 95 thousand plants per hectare. The applied forecrops, method of tillage, dressing and plant protection were identical in both locations. The data about the duration of the emergency (in days), the canopy development after the end of the emergency period, the root lodging, the health condition of the plants, the stalk breaking, the development of the plants and their uniformity were recorded during the whole growing season. The values of these parameters fluctuated within the normal range and there were no marked differences between the two experimental locations.

The silage ripeness of the grain milk line was continuously monitored. The experimental plots were harvested when plants of a given hybrid reached the maturity stage ranging between one and two thirds of the grain milk line. Thereafter, the yield was calculated and the samples of chopped forage were collected for laboratory analyses.

At first, the chopped fodder was dried at the temperature of 55°C for 2 h and thereafter for at least 12 h at 105°C. Dry samples were homogenised in a laboratory grinder with the mesh size of 1 mm. Thereafter, the homogenised samples were analysed by the standard methods according to AOAC (1995), and the following contents were estimated: DM, crude protein, ash, sugars, starch, and crude fibre. The estimation of the neutral detergent fibre (NDF) was determined applying the amylase

Table 1. Characteristics of hybrids

No.	Hybrid	Producer	FAO	Maturity	Plant	Grain	Usage
H1	RUBBEN	CAUSSADE OSIVA	230	E	SG	F	S
H2	DYNAMITE	SOUFFLET AGRO	240	E	SG	F	S
H3	DKC 3507	MONSANTO CR	260	E	NR	F/D	S/G
H4	DKC 3795	MONSANTO CR	260	E	NR	D	G
H5	LG 32.64	LIMAGRAIN C. E.	260	E	SG	F/D	S
H6	SUSANN	SAATEN - UNION CZ	280	EM	NR	F	S/G
H7	NK OCTET	SYNGENTA CZECH	290	EM	NR	D	S/G
H8	DKC 4014	MONSANTO CR	300	EM	NR	D	G
H9	LG 30.311	LIMAGRAIN C. E.	320	EM	SG	F/D	S

E – early; EM – early to medium; SG – stay-green; NR – normal ripening; F – flint; F/D – medium flint dent; D – dent; S – declared for silage; S/G – for silage and grain; G – for grain production

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method according to Van Soest et al. (1991). The digestibility of NDF and the organic matter (OM) were estimated by the *in sacco* method in rumen fluid of cannulated Holstein dairy cows by Ørskov and McDonald (1979), the analytical samples were incubated for 24 h. The cows (yoked, no milking) were fed by the meadow hay (*ad libitum*) with 2 kg of additive mixtures. The statistic values were processed using the software package Statistica 10 (StatSoft, Tulsa, USA). In addition, the methods for analysis of variance ANOVA, the module for analysing full factorial designs (Table 3) and the repeated measures designs (Table 4) were used. The mean differences were separated using the Tukey's range test.

RESULTS AND DISCUSSION

The level of the precipitation and the temperatures as measured in both localities during the period of the last three years are presented in Table 2. The distribution of rainfalls within the framework of the growing season was more favourable in Uhříněves than in Troubsko.

The differences in the weather were manifested ($P < 0.05$) not only by the fact that yields of DM in Troubsko were lower than in Uhříněves (17.5 ± 3.9 vs. 22.0 ± 3.6 t of DM, respectively, ± means standard deviation), but also in the nutritional parameters. In 2012, the lower level of precipitation, obviously caused an increased content of NDF (Table 3) than in the years 2013 and 2014 (474 ± 37.3 g/kg DM vs. 432 ± 35.8 and 420 ± 49.1 g/kg DM, respectively). There were differences also in other parameters. The obtained results corroborated to the observation that the year and the location showed significant effects on maize yield – Farrell and Gilliland (2011) – and the chemical composition of the entire maize plants (Kruse et al. 2008). It is therefore obvious that weather conditions during the growing season affected the growth, the yield, and the nutritive value of the maize plants and their biomass in both locations.

The differences in the content of DM between the individual harvests (at the stage of maturity between one and two thirds of the grain milk line) were small (323 ± 22 g/kg) and found statistically not significant ($P = 0.34$). Ball et al. (1997) determined that for maize the optimum stage for silage making is in the stage of two-thirds of the grain milk line (with some flexibility ranging between one quarter and two thirds of the milk line), i.e. between DM 324 and 350 g/kg, respectively. These authors evaluated the effects of crop maturity on intake, digestion, and milk production. Their experiment was performed with a group of 20 multiparous Holstein cows fed on maize silage in the diet. Carpentier and Cabon (2011) and also Peyrat et al. (2014) recommended that the DM content should be 300–350 g/kg.

There were statistically significant ($P < 0.05$) differences between the individual hybrids in the contents of NDF and the starch in DM (Table 3). As far as all other parameters under the study were concerned (i.e. crude protein, crude fibre, ash, and sugars) no significant differences were found among them and therefore they were not involved into tables. The highest starch content was found in the grain hybrid (H8) with the dent

Table 2. Weather course in Troubsko (T) and Uhříněves (U) in years 2012–2014

Month	Temperature (°C)						Precipitation (mm)					
	2012		2013		2014		2012		2013		2014	
	T	U	T	U	T	U	T	U	T	U	T	U
April	9.5	10.0	9.5	9.8	11.2	11.7	12.1	39.8	18.0	16.7	16.5	32.4
May	16.0	15.9	13.8	12.9	13.8	14.0	25.4	59.3	106	121	58.8	118
June	18.2	18.5	16.9	16.9	18.0	17.5	60.6	60.3	116	150	14.3	32.6
July	20.4	19.6	20.8	20.7	20.8	20.6	60.0	87.1	4.8	43.4	89.7	179
August	19.7	19.8	19.3	18.6	17.0	17.6	72.4	83.4	68.8	105	110	58.6
September	14.5	15.2	12.5	13.0	15.0	15.5	32.1	42.3	48.4	49.3	105	87.6
Mean	16.4	16.5	15.5	15.3	16.0	16.2	43.8	62.0	60.3	81.0	65.8	84.6

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Table 3. Effect of hybrid, year and location on nutritional value

Index	No	DM (g/kg)	NDF (g/kg DM)	NDFD24 (%)	Starch (g/kg DM)	OMD24 (%)
Hybrid (H)	H1	315	448^{ab}	51.0	313^{b}	67.8
	H2	330	466^{b}	52.6	290^{ab}	68.2
	H3	325	450^{ab}	52.4	308^{b}	68.5
	H4	318	448^{ab}	51.8	314^{b}	70.8
	H5	326	451^{ab}	54.9	273^{a}	71.1
	H6	329	439^{ab}	49.3	290^{ab}	66.3
	H7	320	423^{ab}	50.9	306^{ab}	65.9
	H8	322	411^{a}	54.4	350^{c}	68.6
	H9	325	439^{ab}	54.2	302^{ab}	68.8
Year (Y)	2012	329^{b}	474^{b}	55.2^{b}	314^{b}	73.0^{b}
	2013	314^{a}	432^{a}	55.3^{b}	292^{a}	73.4^{b}
	2014	327^{b}	420^{a}	46.7^{a}	309^{ab}	59.0^{a}
Location (L)	Troubsko	332^{b}	426^{a}	50.9^{a}	314^{b}	70.2^{b}
	Uhříněves	315^{a}	458^{b}	53.8^{b}	296^{a}	66.7^{a}
Effect	H	0.34	**0.002**	**0.044**	**< 0.001**	**0.002**
	Y	**< 0.001**	**< 0.001**	**< 0.001**	**0.005**	**< 0.001**
	H × Y	**0.014**	0.102	**< 0.001**	**< 0.001**	**< 0.001**
	L	**< 0.001**	**< 0.001**	**0.019**	**< 0.001**	**0.012**
	H × L	**0.001**	0.605	0.069	0.165	0.731

^{a,b,c} Different letters (superscripts) within a row indicate statistical differences for Tukey´s *HSD* α = 0.05; DM – dry matter; NDF – neutral detergent fibre (with amylase); NDFD24 – digestibility of NDF with 24 h incubation; OMD24 – digestibility of organic matter with 24 h incubation

type of grain endosperm and at a higher FAO number (300). The lowest starch content was recorded in the silage hybrid H5 (stay-green type; FAO number 260). According to Di Marco et al. (2002), the continuing process of crop maturation increased ($P < 0.05$) the content of starch on the one hand, but decreased both the content of NDF and its digestibility (NDFD) on the other.

As starch and NDF are the major sources of nutrients in maize plants, NDFD became an important trait when selecting hybrids for silage making (Lopes et al. 2009). In the case which we present here, the results among the hybrids under the study concerning NDFD as recorded in each year and in each location, are statistically significant. However, because the data were collected in two different locations during three years, the differences between the individual hybrids were diminishing and therefore gradually washed off. Nevertheless, there were differences in the reaction of the individual hybrids to the weather within the study period. This was in line with the data published by Kruse et al. (2008) who reported that variation in fibre content was influenced more by environmental factors and their variation than by genotypic factors.

The types of the hybrids (i.e. their groups with identical parameters) are compared in Table 4. In the Czech Republic, maize hybrids are classified as early (E), i.e. with the FAO index up to 260, and as early to medium (EM), i.e. with the FAO index higher than 260. The time interval necessary for entering into the optimum harvest stage of maturity was shorter by 6 days of E hybrids than that of EM hybrids (131 vs. 137 days). However, their yield was lower than that of EM hybrids (18.9 vs.

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Table 4. Effect of type of hybrids on nutritional value

Index		DM (g/kg)	NDF	NDFD24	Starch	OMD24 (%)
			(g/kg DM)			
Maturity	E	323	453[b]	52.5	299[a]	69.3
	EM	324	428[a]	52.2	312[b]	67.4
Plant	NR	323	434[a]	51.8	314[b]	68.0
	SG	324	451[b]	53.2	294[a]	69.0
Grain	F	325	451[b]	50.9	298[a]	67.4
	F/D	325	447[ab]	53.8	295[a]	69.5
	D	320	427[a]	52.4	323[b]	68.5
Usage	S	324	451[b]	53.2	294[a]	69.0
	S/G	325	437[a]	50.9	301[a]	66.9
	G	320	430[a]	53.1	332[b]	69.7
SEM	n = 162	1.73	3.72	0.63	3.05	0.68

[a,b,c]Different letters (superscripts) within a row indicate statistical differences for the Tukey's *HSD* α = 0.05; E – early; E/M – early to medium; NR – normal ripening; SG – stay-green; F – flint; F/D – medium flint and dent; D – dent; S – for silage; S/G – for silage and grain; G – for grain; DM – dry matter; NDF – neutral detergent fibre (with amylase); NDFD – digestibility of NDF with 24 h incubation; OMD – digestibility of organic matter with 24 h incubation; SEM – standard error of the mean

20.8 t of DM). As compared with EM hybrids, those classified into the E group produced higher amounts of NDF (453 ± 43.8 vs. 428 ± 44.5 g/kg DM), but less starch (290 ± 35.9 vs. 312 ± 37.5 g/kg DM). The degree of maturity influenced neither NDFD nor OMD. Contrarily, Peyrat et al. (2014) demonstrated in their study that maturity showed a small but significant impact on the total OMD in alimentary tract.

The stay-green maize hybrids were cultivated to extend the harvesting period. While the kernels and the rest of the plant of the conventional hybrids ripened simultaneously (in synch), the plants of the stay-green hybrids stayed green and their assimilation process continued for a relatively long time interval after the end of the kernels ripening. It is generally recommended not to harvest these hybrids before the end of accumulation of nutrients in kernels. This can be identified by a black layer at kernel base. In our experiments, the stay-green hybrids contained less starch (294 ± 37.7 vs. 314 ± 37.4 g/kg DM), but more NDF (451 ± 43.1 vs. 434 ± 48.9 g/kg DM) than those ripening normally.

Maize can be also classified according to the types of endosperm of grain as flint, dent or intermediate flint/dent. The type of the grain is defined by the ratio of the hard (flint, vitreous, glassy) and the soft (dent, floury) endosperm (Cone et al. 2008). A higher content of the glassy endosperm can be found in the flint hybrids while those of the type dent show a higher proportion of the floury endosperm. Lopes et al. (2009) in their study on floury and glassy types of grain corroborate that the type of maize endosperm influenced digestibility of starch and NDF in lactating dairy cows. In accordance with laboratory and *in situ* measurements, diets that contained floury and opaque grains of maize hybrids showed a better total-starch digestibility than those containing grains classified as vitreous. In contrast, an apparent total-tract NDF digestibility was lower in dairy cows fed on diets containing floury and opaque maize grains. In our experiments, the hybrids of the flint type showed a higher content of NDF than those of the dent type (451 ± 46.3 vs. 427 ± 48.7 g/kg DM), but a lower content of starch (298 ± 38.4 vs. 323 ± 38.4 g/kg DM) whereas the differences in NDFD and OMD were not significant. The similar results were published by Peyrat et al. (2014): NDFD was not significantly influenced by flint or dent type grain endosperm.

Recommendations concerning the use of hybrids for silage making, grain production and/or both

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are often very disputable. In making a right decision, it is indeed necessary to rely either on (1) the recommendations of sellers of seed material that, however, may be distorted by commercial objectives and interests or (2) the basis of information obtained in a different way. For that reason, results of a correct and independent testing help practitioners estimate a suitable crop and type. In spite of this, the differences between the both groups (i.e. used for silage making and for grain production) were significant in our experiments ($P < 0.05$). As compared with the grain type of the hybrids, those designated for ensiling produced higher amounts of NDF (451 ± 42.2 vs. 430 ± 54.1 g/kg DM) and lower amounts of starch (294 ± 37.5 vs. 332 ± 41.4 g/kg DM).

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