Acta fytotechn zootechn, 25, 2022(4): 259–268
http://www.acta.fapz.uniag.sk

Original Paper

Silage maturity of maize in a foothill area with NIRS method support

Tomáš Mitrík*[1, 2], Andrej Mitrík[2]
[1]*DEWEX, s. r. o., Detva*
[2]*FEED LAB, s. r. o., Spišská Nová Ves*

Article Details: Received: 2022-05-04 | Accepted: 2022-08-15 | Available online: 2022-12-31

https://doi.org/10.15414/afz.2022.25.04.259-268

The aim of this work was to identify and quantify the relationships between the classification of maize (*Zea mays* L.) hybrids into FAO groups and the dry matter content in the dynamics of vegetation development in a foothill area. The work summarises the results of 9 experiments (140 hybrids, 20 FAO groups). Determining dry matter content was made by a combination of gravimetric determination and NIRS method. Dynamics of the development of dry matter content were evaluated at the level of vegetation days and calendar days. The assessment at the level of the calendar day has sufficient informative value and is more suitable for practical use. Climatic factors were expressed by the index of the relative condition of field crops (RK*PP*) and we monitored their influence on the dynamics of the development of dry matter content. We found statistically significant differences in the RK*PP* index between the harvest seasons in each area and at one of the three monitored localities. ±1 unit of RK*PP* means a shift of ±2.66 days of silage maturity. We defined the silage maturity in terms of reaching a dry matter content of 30%. In individual experiments, it was reached on average on the 273rd day, but in a wide range of 40 days. This range was 44 days at the level of individual hybrids and the level of FAO groups. The FAO230 group (the most numerous) range of silage maturity reached 28 days. We have compiled a proposal for a model for the evaluation of silage maize hybrids based on silage maturity. The results show that the use of FAO maturity groups does not provide a suitable basis for estimating silage maturity.

Keywords: maize, hybrids, maturity, FAO maturity groups, vegetation development, dry matter content

1 Introduction

Silage maturity of maize is characterized by dry matter content (and nutrient concentration, but dry matter content is the first and basic factor. The dry matter content of maize silages within the monitored region of Slovakia during the evaluated period ranged from 218 to 432 g/kg, with an average value of 328 ±45.92 g/kg, which represents a very wide range (own unpublished results). This is the result of the simultaneous action of several factors: the genetic potential of the hybrids used, the weather and soil-climatic conditions, the availability of harvesting equipment and other minor factors which ultimately result in consequences in terms of silage production.

Dry matter content, nutrient composition, and nutrient digestibility change dynamically during the vegetative de-velopment of silage maize stands (Horst et al., 2020; Ferraretto et al., 2018). The nutritional value and production efficiency of maize silages are closely related to the dry matter content (Ferraretto and Shaver, 2012) and therefore the dry matter content is considered a basic and characteristic nutrient parameter of maize silages. The goal of silage maize growers is to achieve a dry matter content of about 300 g/kg on each plot at the time of harvest. At this dry matter content of the whole plant, the dry matter of the grain reaches 500 g/kg (Daynard and Hunter, 1975) and the digestibility of starch and neutral detergent fibre decreases with increasing dry matter content (Di Marco et al., 2002). At that time, the optimal vegetation stage (maturity) is also achieved not only in terms of pro-duction efficiency (Ferraretto and Shaver, 2012), but also in terms of minimising losses from silage juices (Basti-man and Altman, 1985). The assessment of the dry matter content of maize crops often uses the "milk line" as-sessment of long-lived grains (Crookston and Kurle, 1988) and was developed by Wiersma et al. (1993). The accu-racy in the dry matter

***Corresponding Author:** Tomáš Mitrík, DEWEX, s. r. o., Vígľaš-Pstruša 802, 962 12 Detva, detached worplace: FEED LAB s. r. o, Magrská 2631/3 052 01 Spišská Nová Ves; e-mail: tm1951@me.com, mitrik@feedlab.sk

content estimation is low for this method (Wiersma et al., 1993; Lauer, 1998). Determining the actual dry matter content of whole silage maize plants is mechanically demanding for sample preparation and pro-cessing, but it provides a reasonably accurate and standard basis for dry matter content assessment and for as-sessment of nutrient composition (starch, NDV, NDV digestibility, etc.).

In the practical planning of the production of canned bulk feeds in the silage maize segment, growers focus on the time synchronisation of the course of vegetation development and maturation of individual stands. In our condi-tions, the strategies for the preparation of sowing plans are focused on the selection of hybrids according to their classification into FAO maturity groups (hereinafter also the "FAO group"). The relative maturity rating system for silage (SRM – silage relative maturity; Kohn et al., 2021) compares the dry matter content of a silage hybrid with the average dry matter content of company evaluations using linear regression, but in our conditions no infor-mation of this type is currently available.

In this work, we focused on gravimetric measurement of dry matter content at different levels of FAO maturity groups and at different levels of vegetation maturity during several growing seasons in the foothills. The basic aim of this work was to characterise and evaluate the relationship between the classification of hybrids into FAO ma-turity groups and the achievement of silage maturity during vegetation development. We monitored silage maturity (day of reaching 30% dry matter content) as a crucial parameter in three basic levels: 1. seasons and experiments, 2. FAO maturity groups, 3. different hybrids within one FAO maturity group. We also compared the baseline for evaluations at two levels: vegetation day (number of days since sowing) and current calendar day and evaluated the differences.

2 Material and methods

During the six growing seasons (2016–2021), in close cooperation with producers and sellers of silage maize hybrid seeds, we performed 9 group experiments at three locations in the region of Central and Northern Spiš (Nová Ľubovňa: 543 m ASL, N 49.059°, E 20.325° – hereinafter NL; Poprad: 710 m ASL, N 49.276°, E 20.684° – hereinafter *PP*; Smižany: 545 m ASL, N 48.961°, E 20.503° – hereinafter SM), which are geographically distributed in a triangle with the length of each side 40 km – 15 km – 40 km (designation of experiments: "LLYYYY", where "LL" is the code for the locality, and "YYYY" is the year). The choice of hybrids for each individual experiment was determined by the seed suppliers according to their intentions (16 companies) and in this respect it can be considered random. A total of 140 different hybrids of silage maize were tested with an FAO group range from 120 to 400 (average repeatability of hybrids in the experiments reached 1.96).

FAO group composition in individual experiments (Table 1) was statistically significantly different (P <0.01) with a mean FAO maturity value of 218 ±36. A total of 1,320 analyses were performed in the following breakdown: POPRAD 2016: 91 analyses; Nová Ľubovňa: 2016–2021: 1,025 analyses; Smižany: 2020–2021: 204 analyses.

The date of sowing hybrids always depended on the current conditions of the given growing season and was executed at in the first possible date when there were suitable conditions for sowing maize. Sowing was performed in the interval of 35 calendar days (from April 24 to May 20, i.e. between the 108th and 143rd calendar day) using pneumatic seed drills in the range of 4–8 rows with a spacing of 75 cm for a length of at least 100 meters and with a sowing density of 75–85 thousand individuals per hectare.

Sampling of whole plants started at the beginning of milk maturity and continued at approximately 7–10-day intervals to the highest possible degree of maturity and vegetation development. The average range of the sampling period was 45 days and ranged from 29 to 59 days. In 2017, heavy frosts ended the harvest in the second half of September, and in other cases there were technical and technological constraints. The sampling periods were spread from the 78th to the 171st vegetation day, which in interpretation into individual seasons represented the 217th to 294th calendar day (Table 2).

Table 1 Characteristics of experiments and FAO maturity groups according to individual experiments

Experiment*	*PP*2016	NL2016	NL2017	NL2018	NL2019	NL2020	SM2020	NL2021	SM2021
FAO**	236^{abcdef}	211^{ab}	199^{acefghi}	201^{adefgh}	218^{acde}	216^{acdfh}	224^{cdg}	228^{cdfh}	224^{cd}
FAO***	9	6	11	12	14	14	10	15	12
Hybrids	17	13	23	35	39	48	16	52	31
Samples	91	60	92	175	193	245	80	260	124
Sowing****	130	143	114	114	139	108	114	139	143

* – designation of experiments in the head (location year); ** – FAO maturity group (average); *** – number of FAO groups represented; **** – calendar day; values in rows with identical index designations are significantly different P <0.01

Table 2 Sample collections

Experiment	Calendar day			Vegetation day		
	from	to	range	from	to	range
*PP*2016	217	274	57	87	144	57
NL2016	235	294	59	92	151	59
NL2017	232	261	29	118	147	29
NL2018	228	268	40	114	154	40
NL2019	231	283	52	92	144	52
NL2020	236	279	43	127	171	44
SM2020	233	267	34	119	153	34
NL2021	227	280	53	88	141	53
SM2021	221	262	41	78	119	41
Average	229	274	45	102	147	45

The individual samples consisted of 5–20 representative plants (average number 8.78) following each other in the middle rows of the sowing strip cut 15–20 cm above the ground. The average weight of the samples was 6.16 ±2.02 kg. The aim was also to minimize the impact of precipitation by postponing collection dates, but this impact could not be completely avoided. The samples were immediately transported to the laboratory, where they were mechanically cut into particles with a maximum length of 3 cm on proprietary technical equipment of our own design.

The chopped mass was thoroughly mechanically homogenized (mixed), and only then were laboratory samples weighing 500–750 grams taken and dried at 60 °C in Memmert UFE 500 and UFE 700 dryers. After drying (16–24 hours), the samples were weighed, and the laboratory dry matter content was calculated.

The dried samples were ground on RETCH SM-100 and TWISTER mills (overflow on a 1 mm sieve). Nutritional parameters (dry matter content, nitrogenous substances, crude fat, ash, NDV, ADV, starch, water-soluble sugars and NDV 30 hours *in vitro* digestibility) were analysed using an NIRS Antaris II FT-NIR Analyser (manufactured by THERMO SCIENTIFIC) using their own validated calibration models. The characteristics of the method for measuring the dry matter content determined the following parameters: calibration model: R^2 0.995, RMSEC – mean quadratic calibration error = 5.64 g/kg; prediction model: R^2 0.994, RMSEP – mean quadratic calibration error 5.54 g/kg). The total dry matter content was evaluated on the basis of the laboratory dry matter content and on the basis of the dry matter content measured by the NIRS method.

We evaluated the characteristics and development of climatic conditions in individual weeks for all seasons and locations. We used an estimate of the relative field crop condition index (RK*PP*) with respect to the normal state of vegetation derived from the data of the 2000–2015 seasons, which is also publicly available at www.intersucho.sk (Začalová and Mrázková, 2018; Turňa et al., 2021). The authors of this system used a MODIS instrument with an aggregated resolution of 5 km with the necessary noise reduction (Trnka et al., 2020).

We performed statistical evaluations with the program NCSS 12 (64 bit) – version 12.0.18 – NCSS LLC (used methods: ANOVA, linear regression, non-linear polynomial regression).

3 Results and discussion

The average value of the RK*PP* index for the whole period and all experiments is 102.26. With the exception of three cases, the RK*PP* index was always above average compared to the reference period (Table 3). The average value of the RKKP index reached a maximum in all three localities in the 2018 season with a value of 106.33. We did not find statistically significant differences in RK*PP* between localities at the level of evaluation of individual weeks (*P* 0.24). We only recorded statistically significant differences (*P* <0.05) between the seasons at the locality of Nová Ľubovňa (NL) and in the 2018 season, an experiment with the highest value of the RK*PP* index was performed at this locality.

3.1 Dry matter content by season and experiment and in relation to vegetation and calendar day

The average daily dry matter growth reached 2.92 ±1.77 g/kg/day and the non-linear polynomial regression coefficient reached a low value of R^2 0.164 (Table 4). We found statistically significant differences between the individual experiments (*P* <0.01). We did not find any relationship by non-linear polynomial regression between

Table 3 Relative condition of field crops (RK*PP*) by season

Experiment	*PP*	NL	SM	Average
2016	103.60	99.40	102.80	101.93
2017	100.00	96.20[ce]	102.60	99.60[c]
2018	104.80	105.80[b]	108.40	106.33[bd]
2019	100.22	101.96	102.39	101.52[c]
2020	98.75	104.58[b]	102.08	101.81
2021	103.40	101.60	101.80	102.27
Average	101.84	101.56	103.37	102.26

values in columns with identical index designations are significantly different at $P < 0.05$

the average daily dry gain and the average climatic conditions (RK*PP*) with R^2 0.069. The average daily dry gain in experiments with one silage hybrid in subtropical conditions in the vegetation stages starting with the ½ milk line stage at the grain value of 4.18 ±1.07 g/kg/day (Saylor et al., 2021) and 4.88 ±1.74 g/kg/day (Rabelo et al., 2015), which is consistent with our results with The average dry matter content of 30% (silage maturity) in the whole set of measurements (*n* 1,320) was reached on the 153rd vegetation day and the 273rd calendar day. In terms of individual experiments, the fastest development in achieving silage maturity was in the NL 2018 season (Figure 1; Table 4). We found the latest date for reaching silage maturity is up to 40 calendar and 36 growing days (Figure 1; Table 4). earlier hybrids in our continental conditions (Figure 4).

The non-linear polynomial regression of the dry matter content of each hybrid in relation to the growing day reached a value of R^2 0.534 and in relation to calendar day a value of R^2 0.570. The average regression coefficient from individual regression assessments of each hybrid at the vegetation day level reached 0.840 (0.313–1.000) and at the calendar day level 0.869 (0.336–1.000) and the differences are not statistically significant (P 0.257; α 0.05).

Table 4 Silage maturity dates according to individual experiments

Experiment	Increment DM (g/day)	Calendar day	Vegetation day
*PP*2016	2.91[dh]	271	141
NL2016	3.18[h]	280	137
NL2017	2.30[dg]	276	162
NL2018	4.04[abefhi]	246	132
NL2019	3.08[di]	277	138
NL2020	3.09[di]	269	161
SM2020	3.79[ci]	266	152
NL2021	1.78[abdefgi]	286	147
SM2021	2.91[dh]	269	126
Average	2.92	273	153
Range	13.3	40	36

values in rows with identical index designations are statistically significantly different ($P < 0.01$)

The multiple non-linear regression coefficient between achieving silage maturity in terms of vegetation and calendar day reached a low value of 0.160 (Figure 2). Between climatic factors (RK*PP* index) and silage maturity, we found a relatively significant relationship at the level of R^2 0.685 (Figure 3). Using linear regression analysis between the term silage maturity and the RK*PP* index, we found the following relationship, which describes the influence of climatic factors on the date of reaching silage maturity of silage maize stands:

silage maturity ±1 RK*PP* unit = ±2.66 (±0.18) day R^2 0.996

Vegetation and calendar day – assessment: every vegetation day belongs to a particular calendar day in a given year, depending on the sowing date. During the development of plants, climatic conditions change dynamically, so this factor plays a dominant role. This

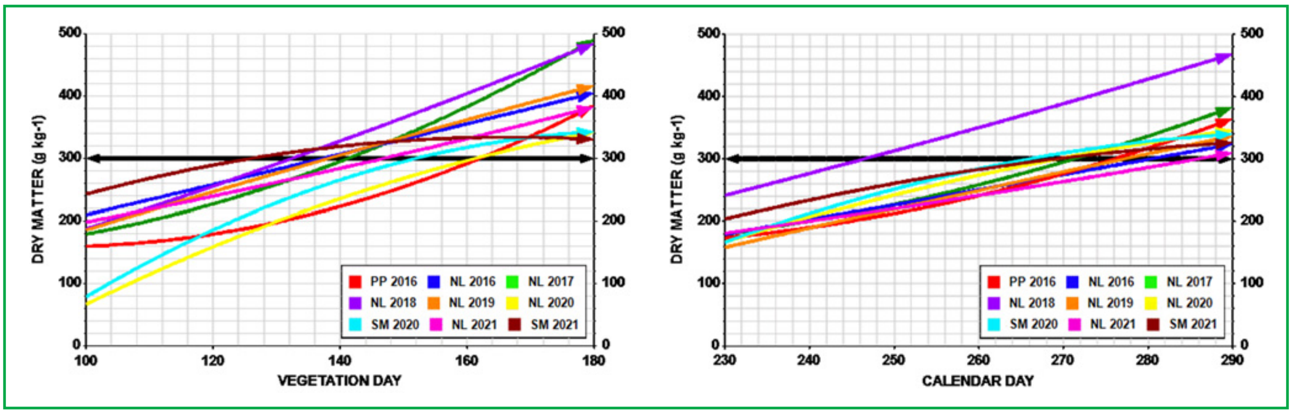

Figure 1 Development of dry matter content in relation to vegetation and calendar day in individual experiments

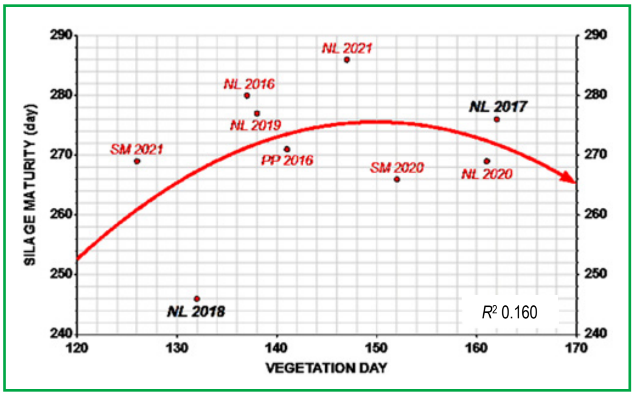

Figure 2 Silage maturity – vegetation day

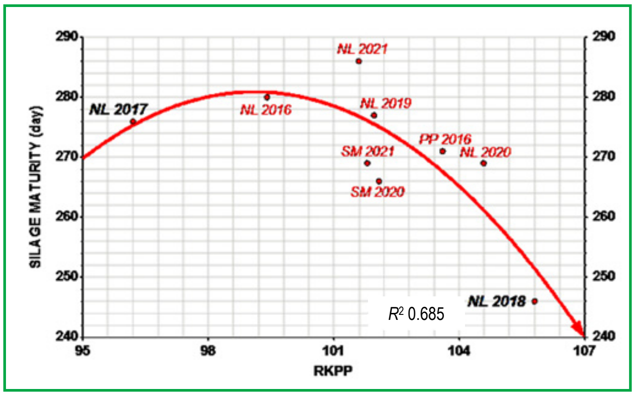

Figure 3 Silage maturity and climatic conditions (RK*PP*)

fact is very well illustrated by a comparison of NL 2017 and NL 2018 experiments: in both experiments, sowing took place on the same calendar day (April 24) and silage maturity was reached 30 days later in the NL 2017 experiment. Very close regression values between dry matter content and vegetation or calendar day at the level of all hybrids together (R^2 0.534–0.570) and at the level of individual hybrids together (R^2 0.840–0.869) indicate there are minimal differences between approaches to assessment. The relationship between the vegetation day at which silage maturity is reached (Figure 2) is relatively very weak (R^2 0.160). Based on these results and conclusions, assessment of development at the level of calendar day for practical applications may be recommended.

A very wide range of silage maturity interval between experiments (40 days) suggests that each season has its specific characteristics (Figure 2, 3). The course of dry matter development between experiments in individual seasons also differ in the dynamics of the course of vegetation development (Figure 1), so even from this point of view we can consider each season uniquely characteristic.

The significantly faster course of growth in the 2018 season is clearly related to the value of the RK*PP* index, which is confirmed by the high values of this index in 2018 (Table 3; Figure 3). Although the experiment in the 2018 season was only carried out at the NL locality, so on the basis of high values of RK*PP* coefficients (Table 3), other sites can also be assumed to have had a significantly faster course of vegetation development and earlier silage maturation in stands. This relationship is necessary and appropriate to verify and confirm with other targeted attempts in the future. The specificity of the climatic conditions of each season is highlighted by the fact that NL 2017 and NL 2018 attempts were sown on 24 April, and their dates of achieving silage maturity were very different (Figures 2, 3).

The strong non-linear regression relationship (R^2 0.685) between climactic factors (RK*PP*) and silage maturity (Figure 4) is also largely strengthened by a linear regression estimate of the effect of changing RK*PP* on the achievement of silage maturity [1]. However, no dynamics in the course of climatic conditions are or can be expressed in the average RK*PP* index, but this relationship may be beneficial for the modelling and preparation of cultivation strategies.

Johnson et al. (2003) monitored the relationship between the chemical composition of three silage maize hybrids in relation to the vegetation stage, defining the vegetation stage by means of the milk line level. At the same vegetation stage, dry matter content of 302 g/kg, 333 g/kg and 356 g/kg was measured in the individual hybrids, which represent significant differences and, which is also in line with our results.

3.2 Dry matter content in FAO maturity groups

The experiments included hybrids of silage maize, which were included in 20 different FAO groups (Table 1). Most of the dry matter content measurements (Table 5) were made in FAO groups from 170 to 260 (>70 measurements/group – more than 5% of the total number of measurements). More than 100 dry matter

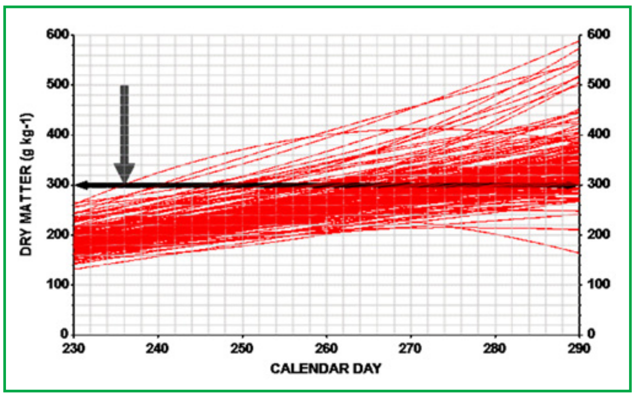

Figure 4 Hybrids – development of dry matter content

Table 5 Dry matter content of FAO groups, scope of the monitored period and silage maturity

		n	Dry matter (g/kg)							Calendar day					
			Ø	SD	95% DIS*	95% HIS*	min	max	range	Ø	min	max	range	silage maturity day	
FAO maturity group	120	10	328.30[gijklmnpqrst]	58.11	287	370	241	414	173	257	236	279	43	248	±47.39
	130	12	280.92	67.33	238	324	191	425	234	251	228	283	55	259	±146.45
	140	14	300.71[jkmnqr]	71.57	259	342	200	440	240	246	228	268	40	247	±104.10
	160	24	281.17[mnqr]	73.19	250	312	162	413	251	253	228	283	55	259	±89.06
	170	100	259.11	65.02	246	272	156	412	256	250	217	294	77	263	±66.90
	180	92	278.50[gijklmnqr]	69.21	264	293	163	445	282	251	221	294	73	256	±99.26
	190	75	243.48[af]	51.55	232	255	145	346	201	248	217	283	66	271	±43.49
	200	137	258.46	57.53	249	268	155	422	267	252	221	294	73	269	±83.49
	210	102	241.41[af]	52.25	231	252	147	381	234	251	221	283	62	277	±64.40
	220	154	235.01[acf]	51.64	227	243	152	386	234	251	217	294	77	277	±54.83
	230	236	239.69[acf]	51.25	233	246	154	361	207	252	217	283	66	274	±51.85
	240	117	240.37[af]	50.46	231	250	147	373	226	251	221	294	73	278	±58.77
	250	86	228.14[acdfh]	44.58	219	238	154	337	183	251	221	294	73	291	±59.20
	260	72	225.98[acdfh]	42.38	216	236	157	329	172	251	221	283	62	291	±57.92
	270	35	228.71[acf]	45.58	213	244	134	319	185	255	227	283	56	284	±46.69
	280	10	212.31[a]	39.78	184	241	157	288	131	252	227	280	53	>300	–
	290	19	214.85[acdf]	39.63	196	234	146	273	127	250	221	283	62	>300	–
	300	14	208.88[acdf]	38.73	187	231	155	273	118	250	221	280	59	>300	–
	340	6	203.04[a]	36.27	165	241	146	248	102	247	217	274	57	>300	–
	400	5	197.02[a]	20.26	172	222	172	216	44	251	227	280	53	>300	–
Ø	218		245.11	53.44	233	257	134	445	222	251	217	294	69		–

*DS and HIS – lower and upper interval of reliability; SD – standard deviation; min – minimum; max – maximum
values in columns with identical index designations are significantly different (P <0.01)

content measurements (7.5% share) were completed in FAO groups: 170, 200, 210, 220, 230 and 240. The most measured and assessed was the FAO 230 group with a total of 236 measurements.

The dry matter content between FAO groups was statistically significantly different (p <0.01) with large differences between groups. In the measurements of 746 hybrids from the most numerous of the included FAO groups (200–240), we did not find a statistically significant difference in dry matter content (Table 5), which also illustrates the uniform distribution of the values of standard deviations, intervals of reliability, and the minimum and maximum values. These results clearly indicate that classification into FAO groups does not describe the development of silage maturity.

The development of the dry matter content was monitored in the range from 217 to the 294th calendar day. The average dry matter content for the individual periods of each FAO group was 134 to 445 g/kg with an overall average of 245.11 g/kg (Table 5). The average dry matter content at the level of individual hybrids differs significantly statistically (p <0.01). Our results are in accordance with changes in dry matter content measured during vegetation development of two hybrids with a 10 -day maturity difference (7 measurements/21 days) in the Row Experiment (2015), which also showed highly significant statistical differences in dry matter content (P <0.01).

Silage maturity at the level of individual hybrids was relatively evenly distributed (Figure 4), but over a very wide period of time: from 236 to 290th calendar day (44 days). 17 of the 140 hybrids (12%) did not achieve the silage maturity threshold by the 290th calendar day. The course of vegetation development in individual hybrids at the calendar day level achieves a statistically significantly different degree of uneven curves (P 0.00). Through linear multiple regression analysis of the time development of dry matter content in calendar days (KalDen) and FAO group (FAO broken down by individual hybrids), we found a relationship with high statistical significance for the parameters of KalDen and FAO (P <0.01), but with a relatively high standard error (±37.87 g/kg):

$$\text{dry matter (g/kg)} = 1.550\ (\pm 0.02) \times \text{KalDen} - 0.655\ (\pm 0.03) \times \text{FAO} \qquad R^2\ 0.977$$

At the level of individual FAO groups, silage maturity was also relatively evenly distributed (Chart 5A), but also over a very wide period of time: from the 247th to 291st calendar day (44 days). A total of 5 of the FAO groups (280, 290, 300, 340 and 400) of a total of 20 groups (25%) did not achieve the silage maturity threshold by the 300th calendar day (Table 5). The dry matter content between FAO groups differs very significantly statistically (p <0.001). The FAO 140 group reached silage maturity first on the 247th calendar day and FAO groups 250 and 260 reached maturity on the 291st calendar day, which in fact is the beginning of the month of October (Table 5B). The range between the earliest and latest dates of reaching silage maturity is up to 44 days. We used linear multiple regression analysis to establish a relationship between FAO group (120–270) and the day of reaching silage maturity:

$$\text{silage maturity (day)} = 0.275 \times \text{FAO} + 215.138 \qquad R^2\ 0.874$$

Every 10 FAO points shifts the achievement of the target critical value of the dry matter by 2.75 days (Figure 5b). FAO groups 280, 290, 300, 340 and 400 did not achieve silage maturity by mid-October, and therefore we did not even evaluate them.

In an experiment conducted by Juráček et al. (2013) under the same growing conditions and with harvest in the same vegetation stage, the FAO 220 hybrid produced a lower dry matter content of 274.7 g/kg, with the FAO 230 hybrid produced dry matter content of 310.5 g/kg and there were statistically significant differences in terms of dry matter content (P <0.05) among four hybrids (FAO 220, 230, 260, 280). Although it was only two hybrids, these results confirm the results that we also found in our work. Similar discrepancies between the FAO group and dry matter content identified in our measurements were also found Bíro et al. (2008).

The achievement of silage maturity for the individual hybrids is distributed into a very long interval of 44 days (Figure 4). For the conditions in which the individual experiments took place, the 290th calendar day is a critical and maximum date. The relatively uniform time distribution of maturation suggests that the differences between hybrids included in individual FAO groups are relatively large and significant. Certain indications of the grouping of hybrids according to the mature groups of FAOs are relatively unclear and begin to appear only around the 270th day. Based on these features, we can assume that FAO groups do not have sufficient potential to provide a description and characteristics of the silage maturity of maize hybrids. The inequality of dynamics during the development of dry matter content in the individual groups (linear regression) is statistically significant (unevenness of curves – P <0.00) and points out that the daily dry matter increment increases with the decreasing value of the FAO group (Figure 4).

The suitability of hybrids for cultivation in the given foothill area is bounded by the FAO 240 group, which on average achieved silage maturity on the 280th calendar day. Hybrids (FAO 250 or more) achieved silage maturity later than on the 280th calendar day, which represents mid-October and are virtually unsuitable for the soil-climate conditions of the foothill area for harvesting maize for silage. The linear regression between the dry matter content, the FAO value and the calendar day is high (R^2 0.977). With knowledge and respect for the standard error (±37.87 g/kg) it may be used as a practical aid to estimate the dry matter content at a given time [2]. The relationship between the development of dry matter content in individual FAO groups is relatively tight

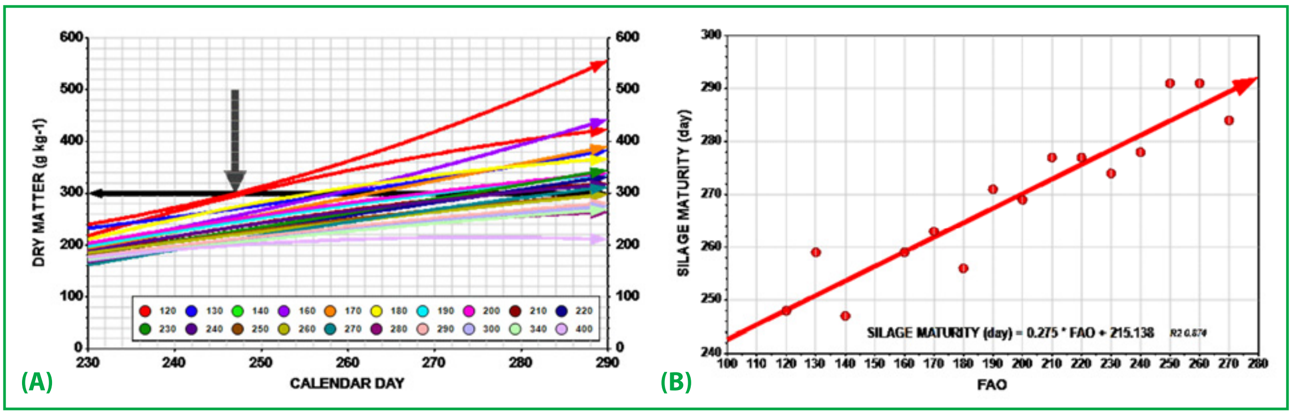

Figure 5 FAO groups and dry matter content (A) - silage maturity of FAO groups 120 to 270 (B)

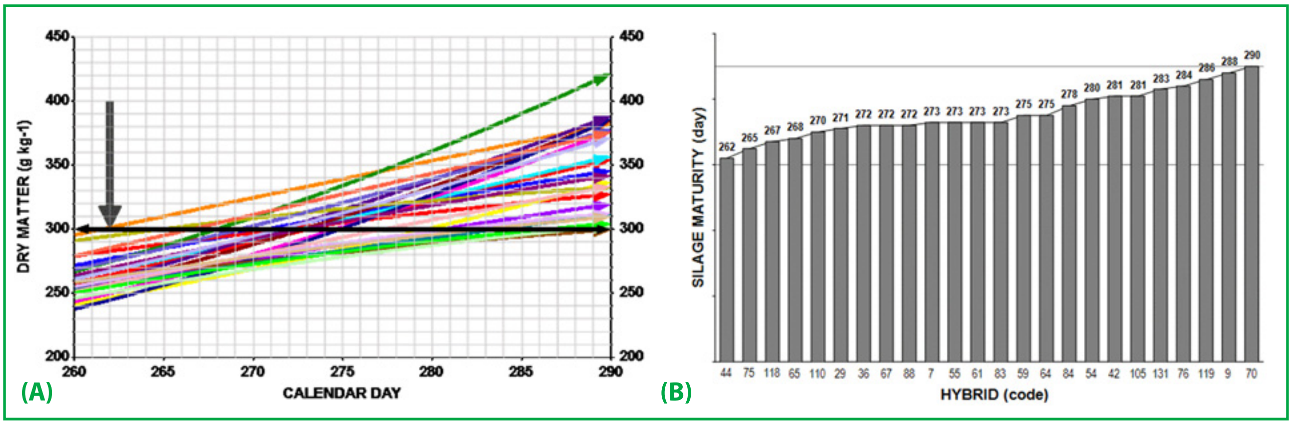

Figure 6 FAO 230 and the development of dry matter content (A) – achievement of silage maturity (B)

(R^2 0.874) and provides a usable planning tool for the climatic conditions [3].

3.3 Dry matter content – hybrids in the FAO 230 group

Finally, we also evaluated the largest represented maturity group FAO 230, which included 24 different hybrids from 11 seed suppliers (Figure 6). The average of individual coefficients of non-linear polynomic regression from FAO 230 hybrids reached R^2 0.877, but the non-linear polynomic regression coefficient combined from all hybrids is only R^2 0.742.

Hybrids included in the FAO 230 group compared to the FAO groups achieved silage maturity in a shorter, but still in a relatively wide period interval: from the 262nd to the 290th calendar day, which represents a total range of 28 calendar days (Figure 6). Silage maturity was achieved on the 275th ±7.3 calendar day on average.

The differences between hybrids included in the largest FAO group (230) are significant even if it is one and the same FAO group. Compared to the level of all hybrids, the achievement of silage maturity was shortened from 44 days to 28 days and the standard deviation reached 7.3. Overall, this range represents a relatively wide time interval. Virtually a third of the hybrids reached silage maturity only after the 280th calendar day (the end of the 1st ten days of October), which represents the borderline for silage maize in the given conditions.

The original methodology for including new hybrids in groups assumes comparison with standard varieties (Jungheimer, 1958) and the whole process includes comparison of the start of flowering, and then comparing gradual achievement of target grain moisture. This methodology in the original, but also in the modified and innovated version (Marton et al., 2004) does not describe any parameter that is related to the silage maturity of maize varieties.

Our results obtained at the level of individual hybrids, at the FAO group level, and at the level of individual hybrids from the same FAO group show that the evaluation and estimation of silage maturity based on the classification of a hybrid to a group does not provide a suitable basis for making a competent decision as to their inclusion in sowing plans in a foothill area.

3.4 Hybrids by silage maturity

For all hybrids, we used regression relationships to assess the date of achievement of silage maturity (SZ), i.e. the (calendar) day of the year in which it is assumed that the dry matter content of 30% will be reached. The entire set included 1,320 measurements. For a uniform distribution of hybrids into groups according to silage maturity, we used the distribution (clustering) technique, which is the standard method in the NCSS 12 statistical application. We have obtained a uniform distribution into five groups (FL) and the group ranges fluctuated from 10 to 14 days (Table 6).

The relationship between the FAO group of individual hybrids and their silage maturity is very loose and achieves a very low and uninterrupted coefficient of non-linear polynomic regression of R^2 0.428 (Figure 7).

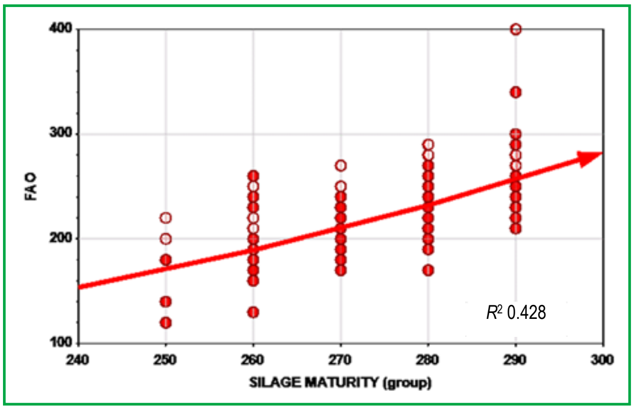

Figure 7 Groups of silage maturity (FL) and FAO group

Table 6 Silage maturity – draft distribution of maturity groups

Group	SilMat* minimum	SilMat* maximum	Range days	Characteristic	Calendar day	Number of hybrids	Working name
1	236	250	14	very early	246	10	FL250
2	253	263	10	early	259	21	FL260
3	265	276	11	medium	271	41	FL270
4	277	289	12	late	282	42	FL280
5		>290		very late	299	26	FL290

* silage maturity (calendar day)

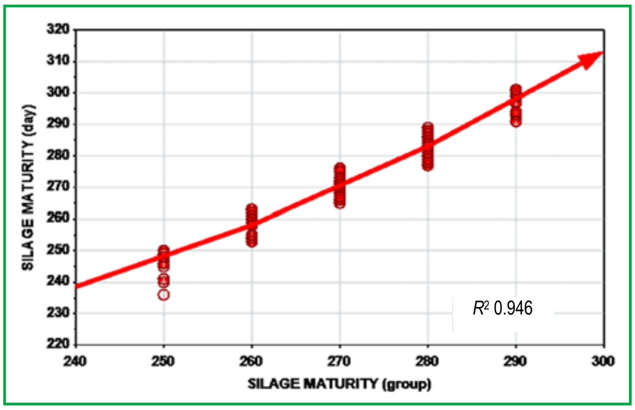

Figure 8 Groups of silage maturity and maturity date

The coefficient of non-linear polynomic regression between the value of the proposed FL groups and silage reached a high rate of mutual dependence of R^2 0.946 (Figure 8). For all hybrids, the relationship between the newly created silage group (FL) and the value of the assigned FAO group is very loose (Figure 8). This documents the weakness in using FAO groups for estimating silage maturity very clearly and illustratively. We are aware that the dry matter content is the most expensive starting point in defining silage maturity, but this distribution already creates a prospective basis for a new and informative classification and definition of hybrid groups based on their silage maturity. From the point of view of organising the harvest and ensilaging, especially in conditions with larger areas of maize stands and a more varied hybrid structure, a range of 10 days provides ample relative space for each group, and therefore measuring the actual dry matter content and nutrient composition at the time just before the expected harvest is appropriate when making a decision as to the start and order of harvesting activities (by parcels).

This raises the prospect that the assignment of selected nutrient parameters can be a system that will create a system that will provide production practice as a serious basis for selecting and classifying hybrids in sowing processes and we want to focus on this issue in future work.

4 Conclusions

Based on the measured values and the regression relations derived there from, two equations were modelled for the foothill area for estimating the date on which the silage maturity of maize hybrids will be achieved and at the same time a model has been created for estimating the effects of changing climatic conditions on the speed of achieving silage maturity. Equations for estimating silage maturity can be used in production practice in planning and preparation of sowing plans.

Acknowledgments

This publication was supported by the Operational Program Integrated Infrastructure within the project: Creation of nucleated herds of dairy cows requiring high health status through the use of genomic selection, innovative bio-technological methods and optimal breeding management (NUKLEUS) 313011V387, cofinanced by the European Regional Development Fund.

References

Bastiman, B., & Altman, J.F.B. (1985). Losses at various stages in silage making. Research and Development. *Agriculture,* 2, 19–25.

Bíro, D. et al. (2008). Fermentation process characteristics of different maize silage hybrids. *Journal of Central European Agriculture,* 9(3).

Crookston, R.K., & Kurle, J.E. (1988) Using the kernel milk line to determine when to harvest corn for silage. *Journal of Production Agriculture,* 1, 293–295.

Daynard, T.B., & Hunter, R.B. (1975). Relationships among whole-plant moisture, grain moisture, dry matter yield, and quality of whole plant corn silage. *Can. J. Planr Sci*., 55, 77–84. https://cdnsciencepub.com/doi/pdf/10.4141/cjps75-010

Di Marco, O.N. et al. (2002). Effect of maize crop maturity on silage chemical composition and digestibility (*in vivo*, *in situ* and *in vitro*). *Animal Feed Science and Technology,* 99(2002), 37–43.

Ferraretto, L.F., & Shaver, R.D. (2012). Meta-analysis: Effect of corn silage harvest practices on intake, digestion, and milk production by dairy cows. *The Professional Animal Scientist,* 28(2012), 141–149. https://doi.org/10.15232/S1080-7446(15)30334-X

Ferraretto, L.F. et al. (2018). Silage review: Recent advances and future technologies for whole-plant and fractionated corn silage harvesting. *J. Dairy Sci.,* 101(5), 3937–3951. https://doi.org/10.3168/jds.2017-13728

Horst, E. H. et al. (2020). Effects of Hybrid and Grain Maturity Stage on the Ruminal Degradation and the Nutritive Value of Maize Forage for Silage. *Agriculture,* 10(7), 251. https://doi.org/10.3390/agriculture10070251

Johnson, L.M. et al. (2003). Corn Silage Management: Effects of Hybrid, Maturity, Inoculation,and Mechanical Processing on Fermentation Characteristics. *Journal of Dairy Science,* 86, 287–308. https://doi.org/10.3168/jds.S0022-0302(03)73607-8

Jungenheimer, R.W. (1958). Hybrid maize breeding and seed production. *FAO Agric. Dev. Pop.t*62), 99–103.

Juráček, M. et al. (2013). Nutritive value and fermentation characteristics of maize silages from different hybrids. *Acta fytotechn. zootechn.,* 16(3), 61–64.

Kohn, K. et al. (2021). Wisconsin Corn Hybrid Performance Trials – 2021 (A3653). Retrieved March 17, 2021 from http://corn.agronomy.wisc.edu/HT/2021/2021Text.aspx

Lauer, J. (1998). Corn Kernel Milk Stage And Silage Harvest Moisture. Retrieved March 17, 2021 from http://corn.agronomy.wisc.edu/AA/A018.aspx

Marton, L.C. et al. (2004). New method to determine FAO number of maize (*Zea mays* L.). *Genetika*, 36(1), 83–92.

Rabelo, C.H.S. et al. (2015). Chemical composition, digestibility and aerobic stability of corn silages harvested at different maturity stages. *Revista Caatinga*, 28(2), 107–116. https://periodicos.ufersa.edu.br/caatinga/article/view/3690

Row, C.A. (2015). Corn Plant Maturity Effect on Yield and Nutritional Quality; Corn Silage Inoculation on Performance of Cattle Fed Silage with or without Live Yeast Added. *Theses and Dissertations in Animal Science*, 110. http://digitalcommons.unl.edu/animalscidiss/110

Saylor, B.A. et al. (2021). Effect of Forage Processor Roll Gap Width and Storage Length on Fermentation Profile, Nutrient Composition, Kernel Processing Score, and Starch Disappearance of Whole-Plant Maize Silage Harvested at Three Different Maturities. *Agriculture*, 11, 574. https://doi.org/10.3390/agriculture11070574

Trnka, M. et al. (2020). Czech Drought Monitor System for monitoring and forecasting agricultural drought and drought impacts. *International Journal of Climatology*, 40, 5941–5958.

Turňa et al. (2021). Projekt INTERSUCHO. www.intersucho.sk

Wiersma, D. W. et al. (1993). Kernel Milkline Stage and Corn Forage Yield, Quality, and Dry Matter Content. *Journal of Production Agriculture,* 6(1), 94–99. https://DOI:10.2134/jpa1993.0094

Začalová M., & Mrázková M. (2018). Drought issues in the Czech Republic and the Intersucho web portal. *Výzkum Chovu skotu,* 60(2), 41–44.