

## YIELD AND FIBRE CONTENT OF MAIZE PLANTS CULTIVATED FOR GREEN MATTER IN POLAND

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### ABSTRACT

**Background.** This work presents the findings of research conducted in 2009–2011 aimed at an assessment of the suitability for cultivation in Poland of selected maize cultivars included in the Common Catalogue of Varieties of Agricultural Plant Species (CCA). Production-related value of the examined cultivars and fibre content determining the quality of feed produced from maize stover harvested at various development stages were assessed.

**Material and methods.** The following two factors were examined in the experiment: A – the harvest date of maize green matter (I – tasseling stage (75% of plants at this stage), II – milk maturity stage (after three weeks), III – wax maturity stage (after another three weeks); B – cultivars with different maturity (Pyroxenia – very early, FAO 130, Codimi – early, FAO 200, Moschus – early, FAO 220, Alombo – medium early, FAO 230, Celive – medium early, FAO 245).

**Results.** The results demonstrated that the highest fresh matter yields were obtained for cv. Alombo harvested at the stage of milk maturity and at the stage of wax maturity, and for cv. Celive harvested at the wax maturity stage.

**Conclusion.** All of the maize cultivars had their lowest content of crude fibre and its fractions when they were harvested at the wax maturity stage.

**Key words:** crude fibre content, fibre fraction content (NDF, ADF), lignin content (ADL), maize, plant fresh matter yield

### INTRODUCTION

In temperate climate countries, including Poland, maize is a raw material used to produce bulk feeds in the form of silage obtained from the whole plants that is intended for dairy cattle (Szempliński *et al.*, 2009). The development of hybrid breeding of maize worldwide, which is resulting in increasingly earlier maturing and more productive cultivars, is an incentive to undertake research including such cultivars under the soil and climatic conditions of Poland. Regardless of the final use of the cultivated maize the major aim of its cultivation is to obtain high cob yield and basic

nutrients (Schittenhelm, 2008; Komainda *et al.*, 2018). Green matter yield and fibre content in maize plants, the content determining the nutritive value of the crop plant, is significantly affected by both the cultivar and the harvest date. As harvest date is delayed the green matter yield and share of cobs in the total yield increases while the crude fibre content decreases, which increases the nutritive value of maize green matter (Yuxiang *et al.*, 2007; Swanckaert *et al.*, 2016). It is worth determining the crude fibre fractions that are components of plant cell walls and they include neutral detergent fibre, acid detergent fibre and structural fibre – acid detergent lignin. As there

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is a paucity of Polish research on the subject the need arises to conduct such studies that are aimed at an evaluation of the suitability for cultivation in Poland of selected maize cultivars included in the Common Catalogue. The production-related value of maize cultivars was evaluated and the crude fibre content and fractions determining the quality of the feed produced from maize plants harvested at various growth stages were assessed.

## MATERIAL AND METHODS

A field experiment was conducted from 2009 to 2011 on a private agricultural holding located in Kowiesy near Siedlce (52°03' N; 22°33' E). The experimental soil was Stagnic Luvisol (classification according to WRB), characterised by a slightly acid reaction (pH in KCl 5.07) and average available phosphorus, potassium and magnesium contents ( $P_2O_5$  12.63 mg·100 g<sup>-1</sup> of soil,  $K_2O$  15.00 mg·100 g<sup>-1</sup> of soil, Mg 4.70 mg·100 g<sup>-1</sup> of soil). Humus content was 1.28%. The experiment was designed as a split-plot arrangement with three replicates. The size of each plot was 30 m<sup>2</sup> (10 m × 3 m). The following two factors were examined: A – maize green matter harvest date (I – tasseling stage (75% of plants at this stage), II – milk maturity stage (after three weeks), III – wax maturity stage (after another three weeks); B – cultivars with different maturity (Pyroxenia – very early FAO 130, Codimi – early FAO 200, Moschus – early FAO 220, Alombo – medium early FAO 230, Celive – medium early FAO 245). Sowing was done by a pneumatic precision seeding machine in the 3rd decade of April at a rate of 100,000 seeds·ha<sup>-1</sup>, 5 cm deep and row spacing of 75 cm. The maize was grown in monoculture. In autumn, cattle manure was applied at the rate of 30 Mg·ha<sup>-1</sup>. In spring, phosphorus and potassium fertilisers were applied at rates appropriate for the soil content of available elements, 60 kg P·ha<sup>-1</sup> and 90 kg K·ha<sup>-1</sup>. Nitrogen fertiliser was spring-applied prior to maize sowing at the rate of 92 kg N·ha<sup>-1</sup>, and the nitrogen rate was increased by 6 kg due to an application of Polifoska 6 (6% N, 20% P, 30% K). It is a multi-component mineral fertilizer containing 6% N. In late April of each of the tested years maize cultivars were sown. Cv. Pyroxenia (Trnava s.r.o. Slovakia, three-way cross (Tc)) is a hybrid characterised by extreme

earliness. Cv. Codimi (Codimes, France, Tc) is an early maturing variety with the classical stay-green trait Cv. Moschus (Freiherr von Moreau Saatzeit GmbH, Germany, modified three-way cross (MTc)) is an early maturing multiple-use variety displaying the stay-green trait. Cv. Alombo (Freiherr von Moreau Saatzeit GmbH, Germany, single cross (Sc)) is a multiple-use variety suitable for both grain and silage production even under poorer soil conditions. Cv. Celive (Cezea a.s., Czech Republic, Sc) is an early maturing hybrid suitable for grain production (Oseva Poland, 2009; Szempliński *et al.*, 2009). During harvest the fresh matter yield was measured and whole plants were collected from each plot for chemical analysis. After drying the following estimates were made: crude fibre, neutral detergent fibre (NDF), acid detergent fibre (ADF) and structural fibre – acid detergent lignin (ADL). The determination method used was near infrared spectroscopy (NIRS) and the spectrometer was a NIR Flex N-500, Büchi Labortechnik AG., Switzerland. The analyses were performed at the certified laboratory of the Institute of Technology and Life Sciences in Falenty. The results obtained were statistically analysed; analysis of variance following the linear model for a two factor split-plot design was performed for each characteristic examined, and separation of means was obtained by means of Tukey test at the significance level of 0.05. Calculations were performed in MS Excel 12.0.

## RESULTS

Fresh matter yields of maize plants differed significantly due to the effect of the experimental factors and their interaction (Table 1).

Higher fresh matter yields were produced by maize plants harvested at the stages of milk maturity and wax maturity, while for plants harvested at the tasseling stage it was significantly lower. Cultivars had a significant effect on the fresh matter yield of maize plants with the highest yield being produced by cv. Alombo. Fresh matter yields of cvs. Moschus, Celive and Codimi were significantly lower compared with cv. Alombo, with there being no significant differences between them. Cv. Pyroxenia had the lowest yield. An interaction between the

experimental factors was confirmed and it indicated that the highest fresh matter yields of maize plants were produced by cv. Alombo harvested at the milk maturity stage and at the wax maturity stage, as well as cv. Clive harvested at the wax maturity stage. The yields were the lowest for cv. Pyroxenia harvested at the tasseling stage and at the wax maturity stage, for cv. Codimi harvested at all of the harvest dates as well as for cvs. Moschus and Celive harvested at the tasseling stage.

**Table 1.** Fresh matter yield of plants (means across 2009–2011), Mg·ha<sup>-1</sup>

Cultivar (B)	Harvest date (A)			Mean
	I	II	III	
Pyroxenia	46.40	57.71	49.89	51.40
Codami	52.02	51.67	54.89	52.86
Moschus	50.11	63.84	61.71	58.55
Alombo	59.60	73.56	68.40	67.19
Celive	52.67	63.78	65.62	60.69
Means	52.20	62.11	60.10	–
<i>Anova</i>	<i>P</i> -value		HSD <sub>0.05</sub>	
Harvest date (A)	<0.001		4.63	
Cultivars (B)	<0.001		6.32	
Interaction (A × B)	<0.001		9.40	

I – tasseling stage; II – milk maturity stage; III – wax maturity stage

Statistical analysis demonstrated that there was a significant effect of harvest dates and cultivars and their interaction on crude fibre content in maize plants (Table 2).

The highest concentration of crude fibre was recorded in stover harvested at the tasseling stage. It was significantly lower at the milk maturity stage and was the lowest at the wax maturity stage. Maize cultivars significantly affected crude fibre content in plants with it being the lowest in cvs. Pyroxenia and Codimi. Crude fibre content of the remaining cultivars was significantly higher. An interaction

between the experimental factors was confirmed: the lowest crude fibre content was found for each cultivar harvested at the wax maturity stage and it was the highest in maize plants of all the cultivars when harvested at the tasseling stage. It should be emphasised that cv. Pyroxenia stood out as the variety that had the lowest crude fibre content at the milk maturity stage.

**Table 2.** Crude fibre content in plants (means across 2009–2011), g·kg<sup>-1</sup> d.m.

Cultivar (B)	Harvest date (A)			Mean
	I	II	III	
Pyroxenia	296.9	204.9	167.3	223.0
Codami	284.0	231.6	166.4	227.3
Moschus	294.7	238.7	182.4	238.6
Alombo	298.6	248.2	181.3	242.7
Celive	290.1	241.4	176.2	235.9
Means	292.9	233.0	174.7	–
<i>Anova</i>	<i>P</i> -value		HSD <sub>0.05</sub>	
Harvest date (A)	<0.001		11.0	
Cultivars (B)	<0.001		12.8	
Interaction (A × B)	<0.001		19.0	

I – tasseling stage; II – milk maturity stage; III – wax maturity stage

NDF content was significantly affected by the experimental factors and their interaction (Table 3).

The highest concentration of neutral detergent fibre (NDF) was recorded in maize plants harvested at the tasseling stage, it being significantly lower in plants harvested at the milk maturity stage and was the lowest when harvest was performed at the wax maturity stage. Of the examined cultivars the lowest neutral detergent fibre (NDF) content was recorded in cvs. Pyroxenia and Codimi. Plants of the remaining cultivars had a significantly higher neutral detergent fibre (NDF) content. An interaction between the experimental factors was confirmed and it indicated that maize plants of all the cultivars harvested at the

tasseling stage contained the highest amount of neutral detergent fibre (NDF), while it was the lowest at the wax maturity stage. The harvest of cv. Codimi at the milk maturity stage resulted in the lowest NDF content.

**Table 3.** Neutral detergent fibre (NDF) content in plants (means across 2009–2011), g·kg<sup>-1</sup> d.m.

Cultivar (B)	Harvest date (A)			Mean
	I	II	III	
Pyroxenia	597.5	439.8	366.2	467.8
Codami	580.7	490.3	370.4	480.5
Moschus	594.7	498.7	394.5	496.0
Alombo	600.6	516.7	391.4	502.9
Celive	585.4	506.7	387.9	493.3
Means	591.8	490.4	382.1	–
<i>Anova</i>	<i>P</i> -value		HSD <sub>0.05</sub>	
Harvest date (A)	<0.001		18.2	
Cultivars (B)	<0.001		22.0	
Interaction (A × B)	<0.001		32.7	

I – tasseling stage; II – milk maturity stage; III – wax maturity stage

Statistical analysis demonstrated a significant effect of the experimental factors and their interaction on ADF content in maize plants (Table 4).

The highest content was recorded in maize plants harvested at the tasseling stage, which is the earliest growth phase. When the harvest date was delayed maize plants tended to contain less ADF. The lowest concentration of this component was recorded in maize plants harvested at the wax maturity stage. ADF content in cvs. Moschus, Alombo and Celive was significantly higher compared with cvs. Pyroxenia and Codimi, with the pattern being similar to that for NDF content. The interaction of the experimental factors revealed that all the test cultivars had their lowest ADF content when harvested at the wax maturity stage and had the highest ADF content when harvested at the tasseling

stage. Of all the cultivars harvested at the milk maturity stage Cv. Pyroxenia had the lowest ADF content.

**Table 4.** Acid detergent fibre (ADF) content in plants (means across 2009–2011), g·kg<sup>-1</sup> d.m.

Cultivar (B)	Harvest date (A)			Mean
	I	II	III	
Pyroxenia	342.8	242.3	192.8	259.3
Codami	332.8	270.5	197.7	267.0
Moschus	341.5	278.1	210.2	276.6
Alombo	346.9	288.9	211.8	282.3
Celive	335.8	282.0	208.1	275.3
Means	340.0	272.2	204.1	–
<i>Anova</i>	<i>P</i> -value		HSD <sub>0.05</sub>	
Harvest date (A)	<0.001		11.3	
Cultivars (B)	<0.001		15.1	
Interaction (A × B)	<0.001		22.4	

I – tasseling stage; II – milk maturity stage; III – wax maturity stage

Structural fibre – ADL content was significantly affected by the experimental factors and their interaction (Table 5).

The highest structural fibre, that is ADL, content was determined in maize plants harvested at the tasseling stage. A delay in the maize harvest resulted in a significant decline in lignin content with it being the lowest in maize plants harvested at the wax maturity stage. Cultivars significantly affected the structural fibre – ADL content. The lowest concentration of this fibre was recorded in cvs. Pyroxenia and Codimi, while in the remaining cultivars it was significantly higher. Although differences in ADL content between those remaining cultivars were insignificant, the highest lignin concentration was determined in cv. Alombo. An interaction between the experimental factors was confirmed. Similarly to the previously discussed fibre

fractions the highest lignin content was found in all the maize cultivars at the tasseling stage with it being the lowest when the harvest was performed at the wax maturity stage. Plants of cvs. Pyroxenia and Codimi harvested at the milk maturity stage contained significantly less lignin than the remaining varieties.

**Table 5.** Acid detergent lignin (ADL) content in plants (means across 2009-2011), g·kg<sup>-1</sup>

Cultivar (B)	Harvest date (A)			Mean
	I	II	III	
Pyroxenia	34.2	24.0	18.9	25.7
Codami	33.4	25.5	20.0	26.3
Moschus	33.7	27.5	21.3	27.5
Alombo	35.8	28.0	21.5	28.4
Celive	33.5	27.0	19.9	26.8
Means	34.1	26.4	20.3	–
<i>Anova</i>	<i>P</i> -value		HSD <sub>0.05</sub>	
Harvest date (A)	<0.001		1.4	
Cultivars (B)	<0.001		2.0	
Interaction (A × B)	<0.001		2.9	

I – tasseling stage; II – milk maturity stage; III – wax maturity stage

## DISCUSSION

Progress in plant breeding and an increasing popularity of maize cultivation in Poland are resulting in this crop plant being perceived positively as far as the production of high-energy silage is concerned. In the study presented here the highest fresh matter yields were produced by maize plants harvested at the milk maturity stage and at the wax maturity stage. At the tasseling stage the fresh matter yield of maize plants was significantly lower. This is probably due to the fact that an increase in maize biomass takes place until plants reach the milk maturity stage. When the harvest was further delayed no fresh matter yield increase was observed. These

findings are in line with reports by Filya (2004), Komainda *et al.* (2018), Szempliński *et al.* (2009), Marcinkowski and Piniewski (2018), Swanckaert *et al.* (2016). The present study demonstrated a higher fresh matter production potential for later maturing cultivars, which is corroborated in research by other authors (Ptaszyńska and Sulewska, 2008; Schittenhelm, 2008; Sulewska *et al.*, 2011; Podkówka *et al.*, 2015; Ali and Anjum, 2017). Under the soil and climatic condition of Poland an increase in the fresh matter production potential of maize in line with an increasing FAO number has been shown (Sulewska *et al.*, 2011; Podkówka *et al.*, 2015). However, cv. Alombo harvested at the milk maturity stage and at the wax maturity stage was the best yielder in the present study. At the wax maturity stage the performance of cv. Celive was the same as cv. Alombo. Podkówka *et al.* (2015), Ptaszyńska and Sulewska (2008) have also demonstrated that medium maturing cultivars deliver higher fresh matter yields.

In the present work a significant effect of maize harvest date on NDF, ADF and ADL was confirmed. The highest crude fibre content, NDF, ADF and ADL were recorded in maize plants harvested at the tasseling stage. When the harvest date was delayed the concentration of crude fibre and its fractions declined and it was the lowest in maize plants harvested at the wax maturity stage. Only NDF content was found to be not significantly different when the maize harvest took place at the milk maturity stage or at the wax maturity stage. This finding is supported by results reported by other authors (Filya, 2004; Jensen *et al.*, 2005; Yuxiang *et al.*, 2007; Ali and Anjum, 2017). According to Podkówka (2015), a correctly produced silage should contain no more than 20% crude fibre. Components of plant cell walls are factors that restrict uptake, digestibility and the energy value of feeds with these components being NDF, ADF and ADL (Belanger *et al.*, 2013; Baert and Van Waes, 2014; Truba *et al.*, 2017). Moreover, many authors (Rodrigues *et al.*, 2008; Belanger *et al.*, 2013; Stejskalova *et al.*, 2013; Truba *et al.*, 2017) conclude that modern methods of feeding cattle should more frequently replace or supplement a determination of crude fibre level with measurements of the NDF, ADF and ADL content

when evaluating feed quality. In the present study crude fibre, NDF, ADF and ADL contents in maize plants were found to be significantly affected by the experimental cultivars. The lowest concentration of crude fibre and its fractions was determined in cvs. Pyroxenia and Codimi, whose respective FAO numbers are 130 and 200. The remaining cultivars, that is Moschus, Alombo and Celive, which have higher FAO numbers, had higher crude fibre, NDF, ADF and ADL contents. Research conducted by Jensen *et al.* (2005) and Podkówka *et al.*, (2015), Schittenhelm (2008) also resulted in similar relationships. This is probably due to the fact that cultivars with a shorter time to reach maturity produce less biomass as the plants are smaller and have more leaves. Also their share of cobs in the green matter yield is higher and that results in a lower content of crude fat and its fractions compared with cultivars whose FAO number is higher and which reach maturity later in the growing season.

## CONCLUSIONS

1. The highest fresh matter yields of maize plants were produced by cv. Alombo harvested at the milk maturity stage and at the wax maturity stage and by cv. Celive harvested at the wax maturity stage.
2. Maize stover of all the examined cultivars had their lowest concentration of crude fibre and its fractions when harvested at the wax maturity stage.
3. The highest fresh matter yield was delivered by cv. Alombo harvested at the milk maturity stage, and the lowest crude fibre, NDF, ADF and ADL contents, necessary to obtain the best quality feed, were found for cvs. Pyroxenia, Celive and Codimi harvested at the wax maturity stage.

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## **PLON I ZAWARTOŚĆ WŁÓKNA W ROŚLINACH KUKURYDZY UPRAWIANYCH NA ZIELONĄ MASĘ W POLSCE**

### **Streszczenie**

W pracy przedstawiono wyniki badań z lat 2009–2011, mające na celu ocenę przydatności do uprawy w Polsce wybranych odmian kukurydzy z Katalogu Wspólnotowego CCA. Oceniono wartość produkcyjną badanych odmian oraz oznaczono zawartość frakcji włókna decydującego o jakości paszy z roślin kukurydzy zbieranych w różnych fazach rozwojowych. W doświadczeniu badano dwa czynniki. A – termin zbioru zielonki kukurydzy: I – faza wyrzucania wiech (75% roślin w tej fazie), II – faza dojrzałości mlecznej (po upływie trzech tygodni), III – faza dojrzałości woskowej (po upływie następnych trzech tygodni); B – odmiany o różnej długości okresu wegetacji: Pyroxenia – bardzo wczesna FAO 130, Codimi – wczesna FAO 200, Moschus – wczesna FAO 220, Alombo – średnio wczesna FAO 230, Celive – średnio wczesna FAO 245. Określono plon świeżej masy roślin kukurydzy. W pobranym materiale roślinnym oznaczono zawartość: włókna surowego, frakcji włókna NDF, ADF oraz włókna strukturalnego – ligniny ADL. Otrzymane wyniki badań pozwalają stwierdzić, że największy plon świeżej masy uzyskano z roślin kukurydzy odmiany Alombo zebranych zarówno w fazie dojrzałości mlecznej, jak i woskowej oraz z roślin kukurydzy odmiany Celive zebranych w fazie dojrzałości woskowej. Rośliny kukurydzy wszystkich badanych odmian charakteryzowały się najniższą zawartością włókna surowego i jego frakcji, jeśli były zebrane w fazie dojrzałości woskowej.

**Słowa kluczowe:** kukurydza, plon świeżej masy roślin, zawartość frakcji włókna (NDF, ADF), zawartość lignin ADL, zawartość włókna surowego