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Maize Varieties Suitable for the Production of Biogas

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The aboveground parts, grain yield, dry matter and water content of the silage maize varieties Bermasil (early) and Mv MSC 485 (mid-season) and the grain maize varieties Mv To 286 (early) and NKPX 9283 (mid-season) were analysed to determine how these traits should be modified to develop a variety type more suitable for the production of bioenergy, more particularly biogas.

It was established that silage maize types are generally taller, with larger tassels, leaves, cobs and stalk mass below the ear, making them suitable for biogas production. It is important to note, however, that the grain yield of these varieties should not be ignored, as it makes up 40–50% of the total aboveground dry matter yield.

As one of the earliest maturing varieties, the silage maize variety Bermasil could be suitable in itself for biogas production. Based on the present and earlier data, it can be concluded that varieties with later maturity dates than those generally used for silage production could also be suitable for biogas production, provided they reliably reach the "half milk line" stage of maturity and a grain moisture content of around 42% every year in the given environment.

Keywords: maize, grain moisture, drying, biogas

Introduction

Growing maize for the purpose of bioenergy (biogas) production is a new sector of maize production. Varieties sown as raw material for biogas are expected to meet a number of special criteria (e.g. maximum dry matter yield per hectare, monoculture tolerance, etc.).

The dry matter yield per hectare is a function of the production conditions, the nutrient and water supplies, the plant density, the length of the vegetation period, the plant height and other plant traits. The greater the yield per hectare, the higher the grain moisture and the moisture content of other plant organs (Hopper 1925; Brown 1962; Gunn and Christensen 1965; Nevens et al. 1954; Rutger 1969; Hadi 1982, 1983a, b, 2004; Hadi and Szundy 1985, 1988, 1990; Berzsenyi and Lap 2006a, b; Marton et al. 2007, etc.).

The continuous production of biogas can only be achieved if the raw material can be stored outside the growing season without quality loss. This can only be ensured if the dry matter content of the stored material is at least 24% (Clark et al. 1973; White and Winter 1979; Sheldrick 1979; Hadi and Szundy 1990).

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The present work aimed to answer the following questions:

1. What changes occur in the water content, dry matter content and dry matter yield of the kernels and other plant organs of various grain and silage maize varieties as a function of the harvest date?
2. What differences can be observed in the dry matter distribution of early and mid-season grain and silage maize varieties and in the water content of the plant organs?
3. As well as distinguishing grain and silage types, how could the maize model ideal for bioenergy (particularly biogas) production be defined?

Materials and Methods

The investigations were carried out on the silage varieties Bermasil (early) and Mv MSC 485 (mid-season) and the grain varieties Mv To 286 (early) and NKPX 9283 (mid-season), grown on chernozem soil with forest residues in Martonvásár in 1987. The experiment was laid out in six rows in four replications, with a plant density of 60,000 plants/ha. At each of five sampling dates (Sept. 11, 17, 24, Oct. 1, 8) the complete aboveground part of five plants per variety per replication was harvested and labelled. The plant organs (tassel, leaves above and below the ear, stalk above and below the ear, ear stalk, cob and kernels) were separated at the nodes. Each part was separately labelled, followed by drying at 95 °C for 96 h, in order to preserve the mass of plant organs with a high water content. The results were evaluated using analysis of variance.

Results

The plant data are presented in Table 1 for each variety, averaged over the sampling dates. As expected, statistically significant differences were noted between the silage and grain maize varieties.

The deviation in the number of husks could be attributed to the genetic background of Bermasil (CM 7) and Mv MSC 485 (Mo 17), as a large number of narrow husks are inherited from CM 7 and a small number of broad husks from Mo 17. The plant height and ear

Table 1. Parameters of silage and grain maize hybrids, averaged over the harvesting dates
Martonvásár, 1987

No.	Parameters	Hybrids				$LSD_{5\%}$
		Bermasil	Mv To 286	Mv MSC 485	NKPX 9283	
1.	No. of husks	13.74	9.19	7.90	8.66	0.54
2.	Kernels/row	34.30	31.58	33.07	32.33	2.02
3.	No. of kernel rows	15.91	14.37	14.11	14.53	0.48
4.	Plant height (cm)	214.65	202.75	208.35	205.85	5.50
5.	Ear attachment height (cm)	86.65	88.75	94.80	88.55	2.60
6.	Ear length (cm)	18.90	18.75	19.02	20.06	0.90
7.	Ear diameter (cm)	4.22	4.17	4.36	4.45	0.11
8.	No. of leaves above the ear	5.48	5.48	5.62	6.12	0.21
9.	No. of leaves below the ear	5.65	6.91	7.83	7.10	0.25

attachment height of silage maize hybrids are generally greater than those of grain hybrids, while later varieties have a larger number of leaves, and silage hybrids generally have more leaves below the ear. (In the case of Bermasil the lowest leaves had already withered and fallen by the later sampling dates.)

Table 2 presents the dry matter yields of the various plant organs. It is clear that the silage varieties tend to have larger tassels. That of Bermasil is extremely large and loose and some of the tassel branches had already withered and fallen by the later stages of ripening.

Table 2. Dry matter yield (q/ha) of silage and grain maize hybrids, averaged over the harvesting dates
Martonvásár, 1987

No.	Parameters	Hybrids				$LSD_{5\%}$
		Bermasil	Mv To 286	Mv MSC 485	NKPX 9283	
1.	Tassel	23.69	25.31	27.12	18.73	1.67
2.	Leaves above the ear	19.43	16.18	15.86	17.86	1.06
3.	Leaves below the ear	17.11	18.81	25.87	21.23	1.23
4.	Husks	10.51	5.98	8.17	6.22	0.73
5.	Stalk above the ear	7.86	5.91	5.52	6.23	0.83
6.	Stalk below the ear	33.01	22.53	28.03	23.19	2.12
7.	Ear stalk	3.13	1.88	2.04	1.75	0.24
8.	Cob	22.27	16.77	18.52	19.27	1.21
9.	Kernels	102.60	95.69	108.97	109.91	9.19
10.	Whole plant	239.61	209.06	240.10	224.39	12.31
11.	Havest index	42.81	45.77	45.38	48.98	2.48

The thin side-branches were also more easily damaged during drying and handling than the shorter, more compact tassel branches of the other three varieties. For this reason the tassel mass of Bermasil could not be determined exactly. Bermasil had more leaves above the ear than the grain maize Mv To 286, and if the withered bottom leaves are also taken into consideration, it probably also had a larger number of leaves below the ear and a larger total number of leaves. This statement is probably also true of the silage hybrid Mv 485 and the grain hybrid NKPX 9283. A further pronounced difference between silage and grain hybrids is the greater mass of the stalk below the ear in silage hybrids, compared with grain hybrids. This is important for fodder maize production, as the high lignin content of the stalk below the ear makes it the least digestible part of the plant. When the crop is used for biogas production, however, the high lignin content is no longer a disadvantage. The dry matter yield of the ear stalk made little contribution to the total dry matter yield per hectare, but a thick cob appears to be desirable, as it made a greater contribution to the total dry matter than the stalk above the ear, and was at par with that of the tassel and of the leaves above and below the ear. Naturally the kernels made the greatest contribution (40–50%) to the total aboveground dry matter yield, which should not be sacrificed in the interests of choosing a very late variety and/or an early harvest date.

The dry matter distribution between the kernels and various plant organs, averaged over five harvesting dates, is presented for each variety in Table 3. When selecting variet-

Table 3. Dry matter distribution in the various plant organs of silage and grain maize hybrids (%)
Martonvásár, 1987

No.	Parameters	Hybrids			
		Bermasil	Mv To 286	Mv MSC 485	NKPX 9283
1.	Tassel	8.7	12.1	11.3	8.3
2.	Leaves above the ear	7.1	7.7	6.6	7.9
3.	Leaves below the ear	6.3	9.0	10.8	9.5
4.	Husks	3.9	2.9	3.4	2.8
5.	Stalk above the ear	2.9	2.8	2.3	2.8
6.	Stalk below the ear	12.1	10.8	11.7	10.3
7.	Ear stalk	1.1	0.9	0.8	0.8
8.	Cob	8.2	8.0	7.7	8.6
9.	Kernels	37.6	45.8	45.3	49.0
10.	Whole plant	100.0	100.0	100.0	100.0

ies suitable for biogas production, importance should be given not only to the grain yield, but also to the dry matter yield of the tassel, the foliage above and below the ear, the cob, and most importantly, the stalk below the ear. For the latter reason, harvesting techniques that leave high stubble are not recommended in the case of biogas production. A comparison of Tables 2 and 3 make it clear that 1987 was a source-deficient year in Martonvásár from the point of view of grain filling. Later-maturing varieties, which have considerably greater yield potential, were unable to manifest this potential. The total aboveground vegetative mass of the varieties examined amounted to: Bermasil 137 q/ha, Mv To 286 113 q/ha, Mv MSC 487 131 q/ha and NKPX 9283 115 q/ha. It appears that higher grain yield per hectare does not necessarily require higher vegetative yield per hectare. This is confirmed by Table 1, which showed that there was no substantial difference in plant height between the late and early varieties studied.

The relative dry matter distribution of the various plant organs, averaged over the sampling dates, is presented for the different varieties in Table 4, from which it is clear that the grain and silage maize varieties formed two distinct groups, in line with previous knowl-

Table 4. Relative dry matter content of various plant organs, averaged over harvesting dates (%)
Martonvásár, 1987

No.	Parameters	Hybrids			
		Bermasil	Mv To 286	Mv MSC 485	NKPX 9283
1.	Tassel	126.5	135.1	149.7	100.0
2.	Leaves above the ear	108.8	90.6	88.8	100.0
3.	Leaves below the ear	80.6	88.6	121.9	100.0
4.	Husks	169.0	96.1	131.4	100.0
5.	Stalk above the ear	126.2	94.9	88.6	100.0
6.	Stalk below the ear	142.3	97.2	120.9	100.0
7.	Ear stalk	178.9	107.4	116.6	100.0
8.	Cob	115.6	87.0	96.1	100.0
9.	Kernels	93.3	87.2	99.1	100.0
10.	Whole plant	106.8	93.2	107.0	100.0

edge on these types. Mv To 286 differed from NKPX 9283 only in earliness and, consequently, in yield. The only other difference was the extremely large tassel of Mv To 286, which could be attributed to the presence among the parental lines of MPS 156, characterised by a large, compact tassel. Bermasil and Mv MSC 485 proved to be extremely similar, the only major difference being the dry matter yield of the leaves below the ear. This could be attributed to the early withering of the lower leaves in Bermasil, which meant that at least 1–3 leaves had been shed by the time the samples were taken.

Discussion

Data on the plant height and on the mass of the leaves above and below the ear, the tassel, the cob and the stalk below the ear indicate that varieties characterised by tall growth, thick stalks and cobs and large tassels are favourable for biogas production, provided these traits are combined with high grain yield. Among the varieties studied, the early variety Bermasil can be recommended for biogas production.

The data from this study do not allow the length of the vegetation period to be evaluated, as the vegetation period in August and September 1987 was source-deficient. Other studies suggest that the grain yield increased significantly between September 17 and October 1, particularly in the later varieties. The mean 100 q/ha grain yield recorded for the varieties cannot be regarded as low, but it is clear that the later-maturing varieties were unable to achieve their greater yield potential. In an autumn with an average rainfall level it is probable that the choice of varieties maturing later than those tested would have led to greater total dry matter yield even if their plant parameters were not significantly higher than those of earlier varieties. The size of the grain yield limits the extent to which it is worth prolonging the vegetation period, as the yield will decline as a function of the length of the vegetation period after the close of the optimum stage, thus leading to a reduction in the total aboveground dry matter yield. It seems likely that only varieties capable of completing the intensive grain development phase will be economical for biogas production. Other experiments indicated that the intensive grain development phase is completed at the "half milk line" stage, i.e. at a grain moisture content of 42%.

In summary, the best varieties for biogas production are late-maturing hybrids that can be reliably expected to reach the "half milk line" stage each year at the given location, while also producing high vegetative mass and grain yield per hectare.

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