The reed canary grass (*Phalaris arundinacea* L.) cultivated for energy utilization

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ABSTRACT: The reed canary grass as a source of energy was tested in field experiments on small plots at three different sites in 1996–2003. The effects of soil and weather conditions, different times of harvest (July, November, March) and different doses of nitrogen fertilization (0, 30, 60 kg/ha) on yields of phytomass were investigated. The effects of the harvest time on the water content in harvested phytomass, loss of phytomass in different harvest period and the content of basic nutrients and heavy metals in plants were all specified. The influence of the year, site and N fertilization on yields of phytomass of the reed canary grass was highly significant. The reed canary grass responded positively to increasing doses of nitrogen by the increase of yields of phytomass. On the averages of years and sites, the N application dose of 30 kg/ha increased dry phytomass yields of the reed canary grass harvested in November by 14.6% (1.08 t/ha). The higher dosage of N 60 kg/ha increased yields of phytomass of the reed canary grass at all sites by 32.8% (2.08 t/ha) on average in contrast with variants without fertilization. By the dose of N 60 kg/ha, the dry above-ground phytomass harvested in autumn was 10.04 t/ha in Ruzyně, 8.27 t/ha in Lukavec and 6.94 t/ha in Chomutov on average over the whole period. The later times of harvest resulted in a decrease of the average yield of phytomass (8.41 t/ha in July, 8.00 t/ha in November and 6.04 t/ha in March) and the average water content (64.3% – 45.2% – 21.5%); on the contrary, energy value of phytomass increased (16.93 GJ/t – 17.02 GJ/t – 17.19 GJ/t). The average content of ash in plants varied from 6.5% in Lukavec to 9.31% in Chomutov. The content of heavy metals in plants never exceeded the highest permissible values set in the Czech Republic for food and feed purposes.

Keywords: reed canary grass; yields of phytomass; energy yield; N fertilization; times of harvest; content of nutrients; content of heavy metals

Recently, it has been possible to note an interest in growing plants suitable for bioenergy purposes. Some grass species with high yield of phytomass can be included among these plants. The reed canary grass belongs to them. It is a native species naturally widespread within the whole territory of the Czech Republic, at all sites with an adequate amount of soil moisture. The reed canary grass is a perennial species without high demands on agricultural practices giving good yields under suitable conditions. There are wide posssibilities for the use of this species, e.g. as feed, thanks to the high content of cellulose in the paper industry or as fuel. This paper is mainly focused on the reed canary grass as a possible source for the power-producing industry.

Field experiments on small plots with the reed canary grass determined for energy purposes were carried out in Research Institute of Crop Production (RICP) in Praha-Ruzyně in 1996–2003 with the aim to study the effects of different types of soil, climate conditions, different times of harvest and different doses of N fertilizaton on yields of phytomass. An effect of the time of harvest on the water content in the harvested material, loss of phytomass during the winter season and the content of basic nutrients and heavy metals in plants were examined as well.

MATERIALS AND METHODS

The field experiments with the reed canary grass (RCG) were performed in 1996–2003 at three different sites (Praha-Ruzyně – RU, Lukavec – LU, Chomutov – CHO). Table 1 gives their soil and weather parameters. Three doses of N fertilization (without N – 0, 30, 60 kg/ha) and three times of harvest (July, November, March) were used in the experiments.

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Table 1. Characteries of experimental sites

Parameter	Experimental site		
	Praha-Ruzyně	Lukavec	Chomutov
Latitude	50°04´	49°37´	50°26´
Longitude	14°26´	15°03´	13°23´
Height above sea level (m)	350	620	363
Soil texture	clay-loam	sandy-loam	sandy-loam
Great soil group	Orthic Luvisol	Vertic Cambisol	Stagno-Gleyic Cambisol
Average annual air temperature (°C)	8.2	6.8	7.6
Average annual precipitation sum (mm)	477	686	525
Agrochemical properties of topsoil:			
Humus content (%)	3.00	3.32	3.58
pH (KCl)	5.57	6.11	5.03
P content (Mehlich II, mg/kg soil)	124.9	131.0	16.6
K content (Mehlich II, mg/kg soil)	126.0	166.0	44.9

P and K fertilization during autumn, uniform for all variants, 26 kg P per ha in the form of superphosphate and 50 kg K per ha in the form of potassium salt, before crop sowing at all sites. No other doses of P and K fertilization were applied during the time of experiments. The sowing rate was 10 kg/ha with rows spacing 12.5 cm. The doses of N (N1 = 30 kg/ha, N2 = 60 kg/ha) were applied as ammonium nitrate with limestone in early spring every year. Since 2001 three times of harvest were used. The first in July, the second during the second half of November, the third in the second half of March. The size of the plots was 15 m^2. The yield of the dry above-ground phytomass, including the water content at the time of harvest and the energy content were determined at all sites in all times of harvest. The energy content was determined as dry matter combustion heat using a calorimeter PARR 1356 according to ČSN 44 1352. The content of heavy metals in phytomass (in the solution of mineralized matter by methods of atomic absorption spectrophotometry followed the common methods and instructions of the producer) and the nutrients in plants at individual times of harvest were determined. The content of nutrients in plants was determined in a solution after mineralization of a sample by concentrated sulphuric acid with addition of a catalyst using mineralizing equipment of the firm Tekator (Sweden) with a reverse distillation of vapours. The results were processed statistically by the methods of analysis of variance and multiple comparison.

RESULTS AND DISCUSSION

The results show that yields of phytomass in the reed canary grass are high dependent on conditions

Table 2. Yields of dry phytomass in the reed canary grass harvested in November at different sites, years and 3 levels of N fertilization during the observed period (t/ha)

Year/Site	N0			N1			N2		
	RU	LU	CHO	RU	LU	CHO	RU	LU	CHO
1996	10.80	3.70	4.30	10.50	5.70	4.00	14.60	6.70	7.10
1997	4.70	6.90	4.80	5.80	7.80	4.60	6.80	8.00	5.70
1998	5.30	11.50	4.40	6.40	14.30	5.00	6.00	15.60	7.80
1999	13.10	3.60	4.60	11.80	7.80	5.74	10.10	9.40	6.94
2000	4.30	3.40	3.81	4.20	3.90	4.47	8.60	4.40	5.05
2001	9.68	3.44	6.23	10.60	4.12	6.84	10.69	3.88	6.40
2002	11.30	8.29	6.10	13.86	9.14	8.08	13.48	10.25	11.80
2003	8.45	6.97	5.57	9.02	7.38	10.18	10.04	7.96	7.76
Year average	8.45	5.98	4.60	9.02	7.52	5.74	10.04	8.27	6.94

Nitrogen fertilization: N0 – no fertilizing, N1 – 30 kg/ha, N2 – 60 kg/ha
Experimental sites: RU – Praha-Ruzyně, LU – Lukavec, CHO – Chomutov

Table 3. ANOVA mean squares for influence of the site, year and fertilization on yields of dry phytomass in the reed canary grass harvested in November

Source of variability	Degrees of freedom	Mean square	*P*
Site	2	70.155	0.0000
Year	7	29.911	0.0000
Fertilization	2	25.866	0.0000
Site × year	14	20.689	0.0000
Site × fertilization	4	0.625	0.8139
Year × fertilization	14	1.181	0.7220
Error	28	1.603	

of stands and years. For example yields of phytomass in Ruzyně ranged on average from 4.2 t/ha in 2000 to 14.6 t/ha in 1996. A similar considerable fluctuation in yields is obvious at other sites as well (Table 2). The fluctuation in yields is mainly dependent on the distribution of precipitations and temperature during the vegetation season at sites and in years. The high yields of the reed canary grass at all sites in 2002 and in Lukavec in 1998 were evidently caused by the above-average precipitations during the vegetation season. In addition, the entire amount of precipitation in Lukavec in 1998 was by 165 mm higher than in Ruzyně for example. Katterer et al. (1998) reached similar results. The analysis of variance (Table 3) showed that the influence of year, site and N fertilization on yields of phytomass in the reed canary grass were highly significant. However, significant interactions between site, resp. year and yields of the reed canary grass were not detected. It means that the influence of fertilization manifested itself similarly at different sites in different years.

The reed canary grass responded to larger doses of N positively by increasing phytomass yields. Applied annually in spring, lower doses of N (30 kg/ha) also led to an increase in average year yields of phytomass at all sites. Averaged over years and sites, the doses of nitrogen 30 kg/ha increased yields of dry phytomass of the annual canary grass harvested in November

Table 4. Year, site and fertilization ranking for average values dry matter yield (t/ha) and their inclusion into the homogeneous groups ($LSD_{0.05}$)

Year	Yields	Homogeneous group
2000	4.678	a
1997	5.122	ab
2001	6.875	abc
1996	7.489	bc
1999	8.120	cd
2003	8.148	cd
1998	8.478	cd
2002	10.254	d
$LSD_{0.05}$	2.765	
Site		
Chomutov	5.760	a
Lukavec	7.255	a
Praha-Ruzyně	9.171	b
$LSD_{0.05}$	1.719	
Fertilization		
N0	6.342	a
N1	7.425	ab
N2	8.419	b
$LSD_{0.05}$	1.839	

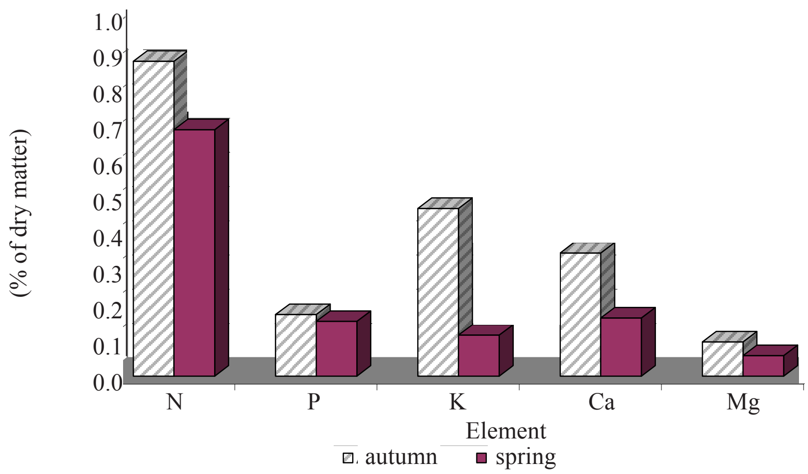

Fig. 1. Content of the main nutrients in reed canary grass in different harvest terms

by 14.6% (1.08 t/ha). A higher dose of nitrogen (60 kg/ha) in the form of ammonium nitrate increased the yields of phytomass of the reed canary grass significantly by 32.8% (2.08 t/ha) on average in comparison with sites without fertilization (Table 4). Adding 60 kg N per ha led during the time of experiments to average yield of dry above-ground phytomass harvested in autumn 10.04 t/ha in Ruzyně, 8.27 t/ha in Lukavec and 6.94 t/ha in Chomutov (Table 2).

Average yields of dry matter of the reed canary grass around 10 t/ha in Kamchatka region were reported by Struzhkina (2002) and average of dry matter phytomass yields 8.5 t/ha in the end of the season and 7 t/ha in spring in Sweden by Landström et al. (1996) were indicated.

The influence of the time of harvest on the water content in harvested phytomass and losses of phytomass were observed as well. Results are given in Table 5. Neither in summer nor in late November, phytomass of the reed canary grass was suitable for immediate burning. We determined the water content 64.3%, 45.2% respectively, in the mentioned times. There are two possibilities in getting rid of the surplus water. Either to desicate crop or to finish the drying in the sun or artificially. It is also possible to harvest in the material in late winter or in spring, untill the grass start growing again, if soil and weather conditions and the occurence of snow allow that. The plants are dried by the first frosts, so the harvest without any other drying along with the immediate following burning are possible. We determined an average moisture in the stand of the reed canary grass around 21% (Table 5), which is the value suitable for direct burning with virtually all types of boilers.

The losses of phytomass during winter were relatively small (around 25% on average – Table 5) in comparison with other plants suitable for energy production (eg sorghum, hollyhock). Similarly for Sweden, Landström and Olsson (1998) give an average yield of dry phytomass of the reed canary grass harvested in autumn and fertilized by the dose of 100 kg N per ha 9.0 t/ha, in spring 7.5 t/ha with dry phytomass content 85%.

The harvest in spring is also recommended for a reduced content of potassium, chlorine, nitrogen and sulphur in phytomass in comparison with the early times of harvest. The amount of the most of elements in plants harvested in spring was lower than in plants harvested in autumn (Fig. 1). Burvall and Hedman (1998), Mortensen (1998) came to a similar conclusion. Translocation of nutrients into a root part and their leaching during winter are considered to be the cause of this phenomenon. For later times of harvest (March–April), the ash caking temperature during burning of phytomass of the annual canary grass increase from 1,070°C to 1,400°C and a lower emission of SO_x and NO_x was determined in comparison with earlier times of harvest (Burvall, Hedman 1998). The reduced content of elements in phytomass harvested in the late period increased the quality of fuel both from the technical and emission production point of view.

The harvest after winter has other advantages as well. In autumn, some stalks of the reed canary grass in some populations tend to form green branches from axils of the leaves, which causes undesirable increase in the water content.

Our results showed that none of the observed heavy metals in plants at all sites reached the highest level permissible for food and feed (Table 6). The content of heavy metals in soils of given sites (Table 6) did not reach the highest permissible values according to the regulation Nr 13/94. So it is not supposed that the observed plants would contain a higher amount of some previously observed heavy metals.

An average content of ash in plants ranged from 6.5% in Lukavec to 9.31% in Chomutov (Table 6) ac-

Table 5. Yields of dry phytomass (t/ha), the water content (%), the heat of combustion of dry phytomass (GJ/t) and the energy yield (GJ/ha) in the reed canary grass at different times of harvest (an average of values for 2001–2003)

Parametr	July	November	March
Dry matter yield	8.410	8.000	6.040
Water content	64.300	45.200	21.500
Combustion heat	16.926	17.024	17.185
Energy yield	142.350	136.190	103.800

cording to the site. The dependence of the ash content in plants of the reed canary grass on the soil type were confirmed by BURVALL (1997) or LANDSTRÖM et al. (1996) as well. BURVALL (1997) showed that the ash concentration in plants was extraordinarily high in soil with a high clay content (10.1%) and low in very humic soils (2.2%). LANDSTRÖM et al. (1996) also found out that the ash content in the plants harvested in spring was lower than in the plants harvested in August.

The reed canary grass has just been introduced as a new source of energy in the Baltic Republics, where it is prefered to the fast growing woody plants. In Sweden or Finland for example (PAHKALA 2001), the reed canary grass should be used as a source for cellulose production (the lignin content is around 14%, the cellulose content 30–36%) or a potential source of energy.

Our results confirm the conclusions of PAHKALA and MELA (1998) that the reed canary grass requires a sufficient amount of moisture and nutrients as well, mainly nitrogen, to give a high yield of phytomass.

Besides the use of the reed canary grass for direct combustion and for electric energy production (combustion heat above ground phytomass dry matter slightly ranged in dependence on harvest time (Table 5) and in average is 17.05 MJ/kg by our measurements), the phytomass can be used in green stage as feedstuff (forage crop, hay, silage) respectively for biogas production. The value of combustion heat in the reed canary grass given for example by BURVALL and HEDMAN (1998) is 17.9 MJ/kg for the reed canary grass harvested in July–August, 17.6 MJ/kg for harvest in March–May. According to the above mentioned authors, this value decreases depending on how late the time of harvest is. According to our results it is exactly the opposite. In our experiments the average value of the combustion heat of dry phytomass in the reed canary grass was recorded 16.93 MJ/kg in July, 17.02 MJ/kg in November and 17.19 MJ/kg in March (Table 5).

Average energy yield from 1 ha in March, i.e. in time when additional energy utilization is unnecessary for after-drying, was 103.8 GJ (Table 5). This amount of energy is fully sufficient for family house heating within all the year or corresponds with the equivalent of 6.5 t (higher quality) brown coal.

The given results indicated that properly established stand of the reed canary grass can stay at one site for many years without reducing the yield. The wider usage of the reed canary grass is supported by low costs of crop establishment, no or low usage of herbicides or pesticides and a low level of other direct costs (STRAŠIL 2000). It is not possible to overlook the fact that in our country the reed canary

Table 6. Content of heavy metals in soils and plants of the reed canary grass (mg/kg) at observed sites (leaching by the solution of 2 M HNO_3, the rate of soil to leaching subject 1:10)

Site	Crop/soil	Ash (%)	Heavy metals content in crop/soils							
			Cd	Pb	Cr	Ni	Co	Zn	As	Cu
Praha-Ruzyně	RCG	8.02	0.20	4.29	0.12	0.61	7.45	0.3	4.93	0.18
Lukavec	RCG	6.50	0.18	3.15	–	0.65	1.15	47.4	–	6.00
Chomutov	RCG	9.31	0.22	7.20	0.10	1.40	0.40	30.1	0.17	3.60
Praha-Ruzyně	Orthic Luvisol		0.25	29.00	2.80	4.70	3.20	22.0	4.40	13.60
Lukavec	Vertic Cambisol		0.21	20.40	11.60	8.60	6.40	31.6	6.90	13.20
Chomutov	Stagno-Gleyic Cambisol		0.22	24.20	6.00	14.30	10.60	54.6	19.20	16.10
CZ standard*)	all soil types exc. light ones		1	70	40	25	25	100	4.5	50

*the highest permitted value – Czech Republic standard
RCG – reed canary grass

grass can be successfully planted under all climatic conditions from the lowlands to the highlands.

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Chrastice rákosovitá (*Phalaris arundianacea* L.) pěstovaná pro energetické využití

ABSTRAKT: V maloparcelkových polních pokusech na třech odlišných stanovištích v období 1996–2003 byla ověřována chrastice rákosovitá určená pro energetické využití. Byl sledován vliv půdně-klimatických podmínek, různých termínů sklizně (červenec, listopad, březen) a odlišných dávek hnojení N (0, 30, 60 kg/ha) na výnosy fytomasy. Byl stanoven vliv termínu sklizně na obsah vody ve sklizeném materiálu, ztráty fytomasy přes zimní období a obsah základních živin a těžkých kovů v rostlinách. Byl zjištěn vysoce průkazný vliv ročníku, stanoviště i hnojení N na výnosy fytomasy chrastice. Chrastice reagovala příznivě zvýšením výnosů fytomasy na rostoucí dávky N. V průměru let a stanovišť zvyšovala dávka 30 kg/ha N výnosy sušiny fytomasy sklízené v listopadu o 14,6 % (1,08 t/ha). Vyšší dávka dusíku 60 kg/ha průkazně zvyšovala na všech stanovištích výnosy fytomasy chrastice v průměru o 32,8 % (2,08 t/ha) proti nehnojeným parcelám. Při dávce 60 kg/ha N bylo dosaženo na podzim za sledované období v průměru v Praze-Ruzyni 10,04 t/ha, v Lukavci 8,27 t/ha a v Chomutově 6,94 t/ha sušiny nadzemní sklizené fytomasy. S pozdějšími termíny sklizně klesal v průměru výnos fytomasy (v červenci 8,41 t/ha, v listopadu 8,00 t/ha, v březnu 6,04 t/ha), obsah vody (64,3 % – 45,2 % – 21,5 %), naopak se zvyšovala energetická hodnota fytomasy (16,93 GJ/t – 17,02 GJ/t – 17,19 GJ/t). Obsah popele v rostlinách kolísal v průměru podle stanovišť od 6,5 % v Lukavci do 9,31 % v Chomutově. Žádný ze sledovaných těžkých kovů v rostlinách chrastice nedosahoval maximálně přípustných hodnot stanovených podle norem v České republice pro potravinové nebo krmné účely.

Klíčová slova: chrastice rákosovitá; výnosy fytomasy; energetická výtěžnost; hnojení N; termíny sklizně; obsah živin; obsah těžkých kovů

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