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YIELD AND QUALITY OF STRAW OF ITALIAN AND PERENNIAL RYEGRASS CULTIVATED FOR SEED PRODUCTION

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Abstract

Italian, annual and perennial ryegrasses are the most important grass species cultivated for seed production in the Czech Republic. The straw remaining after seeds threshing can be used as low quality forage, bedding material or as soil amendment. However, there are no comprehensive information concerning grass straw yields and quality in central Europe. The aim of this study was to investigate the Italian (IR) and perennial (PR) ryegrass straw yield and quality. These parameters were measured for two harvest years at two locations. IR did not provide statistically higher straw yield than PR (7.50 and 7.17 $t.ha^{-1}$ respectively, $p = 0.314$), but dry matter (DM) content immediatelly after threshing was higher than for PR (0.42 and 0.38 respectively, $p = 0.03$). IR straw had the same content of ash and hemicellulose (mean 69.8 and 216 $g.kg^{-1}$DM, $p = 0.22$ and 0.57), but less crude protein (64.1 and 81.4 $g.kg^{-1}$DM, $p = 0.003$), more fibre (399 and 382 $g.kg^{-1}$ DM, $p = 0.02$), NDF (656 and 629 $g.kg^{-1}$ DM, $p = 0.03$) and ADF (442 and 412 $g.kg^{-1}$DM, $p = 0.000$) when compared with PR straw. Most of the parameters were affected by the year (with exception of crude protein) and by location (with exception of yield, DM content, ash and crude protein). There were no differences in mineral nutrient contents between species. The highest values were found in potassium (19.8 $g.kg^{-1}$DM) what is comparable with average quality hay. Phosphorus, calcium and magnesium contents (1.42, 2.96 and 1.02 $g.kg^{-1}$DM) were substantially lower than in hay. Data concerning ryegrasses straw yield and quality from the USA are comparable with our results and can be used for European conditions.

Keywords: grass straw, feeding value, neutral detergent fibre, crude protein, minerals content

INTRODUCTION

Italian ryegrass (*Lolium multiflorum* Lam. ssp. *italicum*) is the most important grass species cultivated for seeds production in the Czech Republic. In 2018 it was grown on the area of 1,964 ha (UKZUZ, 2018), representing 19.6% of area of grasses for seed production. Most of the seeds are used for export to Western Europe, where this grass is used as a winter forage and/or cover crop. Number two species (more correctly subspecies) is annual ryegrass (*Lolium multiflorum* Lam. ssp.

westerwoldicum), propagated on 1,655 ha (16.6%). Perennial ryegrass (*Lolium perenne* L.) is the third one in the order with the area 1,078 ha (10.8%). Similar importance of ryegrasses is documented also in the main world areas for grass seed production as is Oregon (Stamm, 1992), Denmark (Svensson and Boelt, 2008) and New Zealand (Chynoweth *et al.*, 2015).

In past grass straw was commonly used as a fodder for cattle and horses feeding as there was forage deficit in former Czechoslovakia before 1990 (e.g. Demela, 1976). As the number of cattle declined in 1990s there was surplus of grassland forage and the straw was used as bedding material or it was chopped and spread on soil surface before ploughing for improving soil fertility. There were also attempts to use the grass straw as a source of energy (biogas and bioethanol production or direct burning), but cost of handling and transportation made this technologies economically inconvenient (e.g. Eich-Greatorex *et al.*, 2018; Banowetz *et al.*, 2008). In the worldwide largest grass seed production area in the Pacific Northwest USA, field burning of grass straw was a common practice until the middle of 1990s. This method was advantageous for farmers as it was cheap and solved sanitary problems with diseases, pests and weeds, recycled mineral nutrients and supported autumn tillering of the grasses (Stamm, 1992). Due to air pollution, risk of traffic accidents (low visibility along fields) and a hazard of fires spreading to nature, this management is banned (Griffith *et al.*, 2011). American farmers had to find another way of straw disposal and they bale it and offer for erosion control during grassing of slope areas (e.g. road verges), for mushroom production and composting, but the most important market was found in East Asia. Asian farmers purchase straw bales as a source of roughage for their cattle as they suffer from a deficit of fibre rich fodders (Kim *et al.*, 2016). Nevertheless after dry years, there is limited supply of hay and its price rises and especially beef and horse farmers replace lower quality hay by grass straw, if available. Unfortunately there is very limited number of data available concerning grass straw yield and quality evaluation.

The main aim of this paper is to present data concerning production and quality of the straw of the two most important grass species cultivated for seed production in the Czech Republic. Such data from Europe absent in scientific literature and are badly needed both by livestock nutrition consultants and scientists but also by those who evaluate diverse energetic biomass sources and nutrients balances on the farm or field levels.

MATERIALS AND METHODS

Locations and stand management

The trials were conducted in two locations for two harvest years. The basic information concerning the experimental sites is in the Tab. I.

Stands of both species were established in early September 2015 and 2016 respectively in tilled soil and by direct drilling. Stands of Italian ryegrass cv. Lolita and perennial ryegrass cv. Jaran (both forage types, tetraploids) were established in late August or early September using seeding rate 700 of viable seeds per one square meter and row distance 125 mm. There were two soil tillage treatments (ploughed and no till) which were used for yield and dry matter content estimation. Plot size was 10 m^2 and experiment was established in 4 repetitions. As there were good reserves of P, K and Mg nutrients in the soils, only nitrogen fertilizers were used in spring. Nitrogen in ammonium saltpeter form was applied in two doses, 41 kg. ha^{-1} at the beginning of tillering stage in April and 54 kg N.ha^{-1} at stem elongation stage in May. In 2016 was nitrogen applied by mistake in two fold rate in Vatín (41 + 175 kg N.ha^{-1}). Weeds were controlled by herbicide Mustang (a.i. 2,4-D and florasulam) in the rate 0.6 L.ha^{-1} in April. At the end of stem elongation stage growth regulator Moddus (a.i. trinexapac-ethyl) was used in the rate 0.8 L .ha^{-1} as a prevention of lodging. Last treatment was fungicide Amistar (a.i. azoxystrobin) sprayed at the heading against black rust in the rate 1.0 L.ha^{-1}. The harvest was performed by direct combining in July when seeds started to shatter from the spikes.

I: *Characteristics of the experimental sites*

Location	Coordinate	Altitude	Sum of precipitation	Average temperature	Soil type
Vatín	49.52N, 15.97E	540 m	617 mm	6.9 °C	Cambisol
Zubří	49.47N, 18.07E	356 m	864 mm	7.5 °C	Pseudogley

Sampling and chemical analysis

Immediately after harvest, the sample of grass straw was taken from each plot for dry matter (DM) content and DM yield evaluation (determined by drying in forced oven at 55 °C overnight). Samples of dry straw were homogenised by a laboratory mill with openings size 1.0 mm. Three samples from each species, location and year were used from tilled treatment for determining ash, crude protein (CP), fibre, neutral detergent fibre (NDF), acid detergent fibre (ADF) and minerals concentration (P, K, Ca and Mg). Ash content was measured after ignition at the temperature 550 °C for 6 hours. Fibre concentration was determined according to Komarek *et al.* (1996), NDF and ADF concentration by using the method ANCOM (2017a, 2017b). The Kjeldahl method was used to determine N concentration (AOAC, 1984); crude protein was calculated as N content multiplied by factor 6.25. To determine P concentration, a biomass sample was mineralized by acid digestion, treated with molybdovanadate reagent and analysed in a spectrophotometer (ICP OES analyzer, GBC, Australia) at 430 nm (71/393/EEC). To determine K concentration, biomass samples were ashed, dissolved in hydrochloric acid and analysed by flame photometry in a spectrophotometer in the presence of caesium chloride and aluminium nitrate (71/250/EEC). To determine Ca and Mg concentrations, biomass samples were ashed, dissolved in dilute hydrochloric acid and analysed by atomic absorption spectrophotometry at 422_7 (ISO 6869:2000) and 285_72 nm (73/46/EEC), respectively.

Statistical analysis

The experiments were established in block design with randomly replicates. The differences between species, locations and years were statistically evaluated by a multi- and one-way ANOVA. The relationship between seed and straw yield was tested using correlation analysis. All statistical procedures were performed using Statistica 12.0 (STATSOFT, Tulsa, OK, USA).

RESULTS AND DISCUSSION

The effect of species, location and year

The Anova revealed significant effect of species on several parameters as DM content in harvested straw, CP, fibre, NDF and ADF content. Location (different soil and weather conditions) affected significantly DM content of the straw and yield, ash and CP content. Year (weather) affected all parameters with an exception of CP content (Tab. II).

Yield and dry matter content

Grass straw DM content and yields are presented in Tab. III. As the DM content is below 50% (immediately after direct combining) it is necessary to cure the straw before baling. DM content was affected mainly by location due to drier weather in Zubří before harvest. Italian ryegrass had higher DM content than perennial, probably due to lover leaves proportion. Some farmers use two-stages/windrow harvest and in this case straw is usually dry enough after the threshing. Straw yield is a crucial parameter

II: *Results of analysis of variance, testing the effects of species, location and year*

Parameter	Source of variation		
	species	location	year
DM content	*	***	*
DM yield	ns	***	***
Ash	ns	***	*
CP	**	***	ns
Fibre	*	ns	***
NDF	**	ns	***
ADF	***	ns	***
Hemicellulose	ns	ns	***

*, **, *** – significant at the 0.05, 0.01 and 0.001 probability level, respectively;
ns – not significant at the 0.05 probability level

from the view of point farmer's calculations of work load and estimation of amount of biomass usable as a bedding material, forage or for energy production. The straw yield is also needed for mineral nutrients and organic matter balance calculations within crop rotation.

Ryegrasses straw yield was affected by year when in 2016 was more favourable course of weather for grasses growth. In location Zubří higher straw yield was achieved due to lover decline in 2017. There were no differences in straw yield between tested species. The mean straw yields achieved in experiments are much higher than hay yields from permanent grasslands (2.52–3.76 t.ha^{-1}) and comparable with production of perennial forages on arable land (5.50–7.74 t.ha^{-1}) in the Czech Republic in last ten years (CSO, 2018)

There is limited number of information concerning ryegrass straw yields in literature. Our results are consistent with data available from Oregon (Banowetz *et al.*, 2008; Turner *et al.*, 1995). The authors showed the average ryegrass straw yields in the range of 6.25–8.94 tons of dry matter per one hectare. Great range of yield variation in our experiment (2.40–11.44 t.ha^{-1}) was caused mainly by the drought in September 2016 which suppressed the plants emergence and caused gaps in the stands in both stands (see Tab. III). The higher boundary of the range confirms a great production potential of this stands. As the straw yield decline was also accompanied by considerable seed yield reduction, we tested the correlation between the ryegrass seed and straw yield. Although there was a great variability among the values, R - squared was significant with $r^2 = 0.400$.

Taking into account that the cost of straw production is covered by selling grass seed, the realization of straw should represent an increase in farmers' profit. This is big advantage when we compare grass straw with other crops produced intentionally as fodder or energetic biomass source (Banowetz *et al.*, 2008).

Feeding quality

Grass straw is often used as an alternative forage namely after periods of drought and after fires or floods when hay is in short supply and its price is high (e.g. Jenkins *et al.*, 2011). Farmers often consider grass straw as forage of the same quality as a cereal straw. In fact grass straw contains more leaves and finer stems resulting in higher content of crude protein and minerals and has higher dry matter digestibility (Zeman *et al.*, 1995; Stamm, 1992; Van Soest *et al.*, 1982).

Nevertheless when grass straw is used as forage, it should be taken into account, that it consist mostly of cell walls in the form of cellulose, hemicellulose and lignin. Cell walls (NDF) content represented in our samples 53–75% of DM (Tab. IV). Grass straw provides a good source of energy for ruminants and horses, but when compared with good quality hay, its intake is limited by lower digestibility and palatability. Thus it is unsatisfactory nutrient source, without feed supplements, in rations for high-producing dairy cows, lactating beef cows, or young livestock that require high protein content and highly digestible feeds (Turner *et al.*, 1995).

There are two other problems connected with grass straw feeding. The first is that usually several pesticides (herbicides, fungicides, insecticides and plant growth regulators) are applied on the plants during grasses cultivation. Their residues can harm animals. Nevertheless there is usually sufficient time between their application and the harvest and the possible feeding. Also cereal straw is commonly used as a bedding material, and frequently also as a cheap and consistent source of fibre in cattle diets. It is then also consumed by animals though many pesticides were used during its production and there are no restrictions. The latter problem is alkaloids presence in some grasses. These alkaloids are produced by endophyte fungi *Neotyphodium* spp. which live inside of the grass tissues and protect plants against herbivores and environmental stresses (e.g. Rottinghaus *et al.*,

III: *Straw yield and its dry matter (DM) content according to species and location (± significant difference)*

Species	Location	n	Straw DM yield (t.ha^{-1})	Range of yield variation	Straw DM*	Range of DM variation
Italian ryegrass	Vatín	16	6.00 ± 1.76	3.15–11.29	0.41 ± 0.08	0.31–0.53
	Zubří	16	9.01 ± 2.76	2.40–10.48	0.44 ± 0.07	0.32–0.54
Perennial ryegrass	Vatín	16	5.81 ± 1.51	3.68–11.44	0.37 ± 0.07	0.29–0.48
	Zubří	16	8.53 ± 2.36	3.20–10.93	0.40 ± 0.06	0.30–0.50

* dry matter content in the straw measured immediately after the combine harvest

1991). Ocurrence of these fungi and associated alkaloids represents common problem in the USA and New Zealand. Forage and straw of perennial and Italian ryegrasses are linked with a presence of an ergot alkaloid lolitrem B produced by fungus *Neotyphodium lolii*. Toxicity is expressed when the concentration of this alkaloid is higher than 2,000 ppb in dry matter of the animals' diet (Fisher *et al.*, 2004). Typical signs of the toxicity are high body temperature, staggers, and lower fodder intake, sloughing of ears, tail and feet (Rottinghaus *et al.*, 1991). In the Czech Republic an absolute majority of forage grasses cultivars are endophytes free (Cagaš, 2014; Cagaš *et al.*, 2009).

There are significant differences in some parameters of feeding quality between species. Perennial ryegrass contain more crude protein, less fibre, NDF and ADF what make it more suitable for animals' nutrition. The reasoning could be linked in higher leaves content of perennial ryegrass due to its higher persistence and its lower height (lower need of mechanical, supporting tissues). Higher feeding quality was found in 2017 when lower yields both straw and seeds were reached. Weaker stands produced less mechanical tissues (fibre, NDF, ADF) and more CP and minerals (less diluted in lower biomass).

The highest constriction of grass straw when used as a forage for lactating and growing animals is low CP and high fibre concentration. When our results of nutritional value in Tab. IV compared with reviewed American data from Tab. VI, we can see that our straws are slightly higher in CP and in ash, which can be attributed to a higher nitrogen fertilizing and less precipitations immediately before and after harvest which causes soluble nutrients leaching. Unfortunately none of the authors who presented grass straw quality had described grass seed crop management. When grass straw is used for pregnant beef cows feeding during winter season, minimal CP concentration of the whole diet should be above 90 $g.kg^{-1}$ DM (Turner *et al.*, 1995). The nutrients concentration in ryegrass straws was quite stable with an exception of crude protein. In this case the variation coefficient was three-fold as high (41.8 and 43.1%) as for other nutrients (9.9–16.7%). The reason was

IV: *Content of nutrients in the ryegrass straw ($g.kg^{-1}$ DM), averaged two locations and years (Vatín and Zubří, harvested 2016 and 2017), (± significant differences)*

Species	Ash	CP	Fibre	NDF	ADF	HC
Italian ryegrass	68.3 ± 8.1	64.1^{a} ± 26.8	399^{b} ± 52.4	656^{b} ± 76.5	442^{b} ± 43.3	215 ± 35.8
Perennial ryegrass	71.3 ± 11.1	81.4^{b} ± 35.1	382^{a} ± 47.9	629^{a} ± 69.0	412^{a} ± 42.7	217 ± 31.5

Abbreviations: CP – crude protein (= N x 6.25), NDF – neutral detergent fibre, ADF – acid detergent fibre, HC – hemicellulose (= NDF – ADF); means within a row followed by the same uppercase letter were not significantly different at $P \leq 0.05$.

V: *Comparison of ryegrasses straw CP content, DM yield and export of nitrogen at two locations with different nitrogen rate in 2016*

Location	Species	CP content in straw ($g.kg^{-1}$ DM)	Straw yield (kg $DM.ha^{-1}$)	Nitrogen export in straw ($kg.ha^{-1}$)
Vatín (216 kg $N.ha^{-1}$)	Italian ryegrass	98.0	8,530	133.8
	Perennial ryegrass	104.2	8,020	133.7
Zubří (95 kg $N.ha^{-1}$)	Italian ryegrass	29.4	9,100	42.8
	Perennial ryegrass	43.9	8,080	56.7

VI: *Reviewed nutritional value of perennial ryegrass straw from literature ($g.kg^{-1}$ DM)*

Parameter	Fisher *et al.*, 2004	Guggolz *et al.*, 1971	Kellems, 1985	Stamm, 1992	Van Soest *et al.*, 1984	Younberg and Vough, 1977
CP	46–62	55	42–69	36–94	-	49–67
Ash	50	67	-	-	-	-
NDF	630–670	-	688–717	605–742	655–698	681–721
ADF	310–340	506	425–440	379–490	372–374	423–455

probably higher nitrogen fertilization in Vatín in 2016. The differences are shown in Tab. V.

Higher rate of nitrogen fertilizer used in 2016 caused marked increase of crude protein concentration (2.4–3.3 fold higher) but did not increased straw yield. It was probably linked with late nitrogen application and by low sum precipitations after nitrogen application until the stands harvest which prevented straw yield increase and plants lodging.

Next to the most commonly stated parameters shown in tables IV and VI, there are Ocasionally presented also further indicators of grass straw quality as pectins with the concentration 24 g. kg^{-1} DM (Guggolz *et al.*, 1971), In Vitro Dry Matter Digestibility in the range 435–615 g.kg^{-1} DM (Stamm, 1992), lignin 31–43 and cellulose 328–343 g.kg^{-1} DM (Van Soest *et al.*, 1984). All these samples originated from the USA.

According Van Soest (1982) NDF concentration is a primary factor limiting DM intake and is inversely proportional to in vitro digestibility. Our results are comparable with the American sources (629–656 vs. 605–721 g.kg^{-1} DM). Van Soest *et al.* (1984) found much higher NDF content in wheat and barley straw (794 and 842 g.kg^{-1} DM resp.) in comparison with ryegrass straw (see Tab. VI). These annual species have to support heavy spikes and the culms need to be more strengthen.

Fisher *et al.* (2004) found out dry matter intake of annual ryegrass straw dominant diet with soybeans meal supplementation at young bulls as high as 19.4 and 2.4 g.kg^{-1} of body weight respectively. Similar values were presented by Kim *et al.* (2016) who tested feeding of annual ryegrass straw to wether lambs. In the latter study straw DM intake was 20 g.kg^{-1} of body weight. It was found out that DM intake and digestibility of fibre rich forage can be raised by extending of feeding period. Longer time duration of low quality forage feeding increase digestibility and nutrients utilization by animals due to slow adaptation of rumen microbes to high fibre diet (Bruinenberg *et al.*, 2002). Also Ichinohe and Fujihara (2008) suggested that lengthening of feeding over 30 days might cause improving in utilization of energy and protein when fed diets having low ruminal degradation synchronicity between organic matter and nitrogen to adult rams at a maintenance level of feeding.

Minerals

There are no easily available data concerning minerals content in grass straw in literature. Their content is not limiting factor as mineral supplements are standardly offered to animals. Low concentration of calcium in the grass straw (c. 30% compared with meadow hay) is adventitious in the diet for pregnant cows c. ten weeks before calving as it decrease the risk of parturient paresis (e.g. Bode and Cole, 1956, Tucker *et al.*, 1992). Grasses consist generally c. 50% of calcium in comparison with dicot plants (e.g. Whitehead, 2008)

Banowetz *et al.* (2008) point out that high potassium and other minerals content cause a difficulties during heat production (grass straw combustion) as they form glassy euteclic slug which damage the boilers. Concentrations of four mineral elements in ryegrass straw from our experiments are presented in Tab. VII. The highest concentration was found out at potassium, while the lowest for magnesium. The concentration of the main four mineral elements in grass straw is c. 50% in comparison with grasses herbage harvested in vegetative stage (Whitehead, 2008). The only exception is potassium, which concentration in straw is reduced only by 10–30% lower compared with species-rich meadow hay (e.g. Mládek *et al.*, 2012), but it is still far above the requirements of cattle (5.0–9.0 g.kg^{-1} DM, Whitehead, 2008). Phosphorus concentration in this ryegrasses straw is as much as twice higher than in cereals' straw presented by Zeman *et al.* (1995), who show 0.7–0.8 g P.kg DM.

Phosphorus content in ryegrass straw is much lower than in standard meadow hay. The reason is that the phosphorus concentration declines with increasing maturity of the herbage (Whitehead, 2008). In the case of hay made from flower-rich meadows, where soil available phosphorus is usually very low there can be also

VII: *Mineral nutrients content in the straw of two ryegrass species (g.kg^{-1} of DM) (± significant differences)*

Species	P	K	Ca	Mg
Italian ryegrass	1.43 ± 0.60	20.5 ± 5.63	2.99 ± 0.37	1.09 ± 0.48
Perennial ryegrass	1.40 ± 0.36	19.2 ± 2.78	2.93 ± 0.75	0.95 ± 0.12

No significant differences in the elements concentrations were found between both species.

VIII: *Amount of plants nutrients (kg.ha^{-1}) exported from the soil with ryegrass straw (pooled values)*

Species	P	K	Ca	Mg
Italian ryegrass	10.7	153.8	22.4	8.2
Perennial ryegrass	9.5	130.9	20.0	6.5

low concentrations in such a hay. Mládek *et al.* (2015) found out in a hay from White Carpathian meadows (*Cynosurion* and *Violion* alliances) phosphorus concentration 1.5–1.7 g.kg^{-1} DM, what is comparable with the values we analysed in the ryegrass straw cultivated on arable land.

Calcium and magnesium contents are much lower (c. 30–50%) compared to meadow hay and comparable with these found in spring barley straw (3.1–3.2 g Ca and 1.3–1.8 g Mg.kg^{-1} DM, in Zeman *et al.*, 1995).

Although the minerals concentration in straw is not crucial for animals' diets, it plays an important role in plants' nutrients balance in a field and farm level. Export of the nutrients when grass straw is harvested should be replaced by nutrients from fertilizers. Surprisingly the farmers in the USA often relieve of the straw without the need to compensate the price of the minerals (Turner *et al.*, 1995). In the case when there are no animals at the farm, it is usually the most profitable measurement to disintegrate the grass straw and leave it for decomposition on soil surface (Havland *et al.*, 2010). It improves soil fertility and sustainability of the system (Griffith *et al.*, 2011).

In Tab. VIII average amount of exported minerals from the area of 1 hectare is calculated when ryegrass straw is carried away. The nutrient exported in the highest amount is potassium, what can cause a rapid soil deficit when the straw is exported from the farm. The other nutrients are exported in much lower quantities.

CONCLUSION

This paper examines the yield and quality of Italian and perennial ryegrass straw after the seeds harvest. Both species produced comparable straw yields. Italian ryegrass contained less crude protein, more fibre, NDF and ADF compared with perennial ryegrass. Crude protein content in the straw was markedly increased by higher nitrogen fertilizing in contrast to the straw yield. When the ryegrass straw is used for feeding purposes its quality is higher compared with cereal straw in terms of higher minerals and CP content and lower fibre, NDF and ADF concentration. Concerning minerals concentration, grass straw contains high potassium level (corresponding to meadow hay) but lower level of phosphorus, calcium and magnesium. Calculation of the nutrients balance when ryegrass straw is exported from the farm shows substantial amount of elements which should be integrated to the straw price.

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