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Research Article

Variability of yield and forage quality between three heading groups of English ryegrass (*Lolium perenne* L.) during the first growth

Variabilität von Ertrag und Futterqualität zwischen drei Reifegruppen von Englischem Raygras (*Lolium perenne* L.) im Verlauf des ersten Aufwuchses

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Summary

Lolium perenne L. (Lp) is one of the most important and valuable forage plants in grasslands and an indispensable component of seed mixtures for meadows, pastures, ley farming, and re-seeding measures. A set of 39 different cultivars of Lp assigned to early, intermediate, and late maturing types were harvested and analyzed in weekly intervals during the first growth at AREC Raumberg-Gumpenstein, Austria. Significant differences between the heading groups were found with a time lag of 6 days for crude protein content and of up to 11 days for digestibility of organic matter and energy concentration. The early heading cultivars significantly differed from the other two groups, which performed comparably and were more resilient in terms of quality aspects for a longer time. Within all three heading groups, a strong variation could be noticed, leading to some unexpected overlapping. Our results indicate that the current assignment of Lp cultivars to the heading groups is imprecise and should be improved by advanced recordings and by analyses during the time of the official variety testing period. This may lead to a more sufficient selection of Lp cultivars for grassland mixtures, and therefore, increase the quality of home-grown forage.

Keywords: grassland species, English ryegrass, cultivars, heading groups, persistence

Zusammenfassung

Lolium perenne L. (Lp) zählt zu den wichtigsten und wertvollsten Futtergräsern im Grünland und ist ein unverzichtbarer Bestandteil von Saatgutmischungen für Dauerwiesen, Dauerweiden, Feldfutter sowie Nachsaaten. 39 unterschiedliche Lp-Sorten aus der frühen, mittleren und späten Reifegruppe wurden an der HBLFA Raumberg-Gumpenstein (Österreich) zum ersten Aufwuchs in wöchentlichen Abständen geerntet und analysiert. Es zeigten sich deutliche Unterschiede zwischen den Reifegruppen mit einer zeitlichen Verschiebung von 6 Tagen beim Rohproteingehalt sowie von bis zu 11 Tagen bei der Verdaulichkeit der organischen Substanz und der Energiekonzentration. Die frühe Reifegruppe unterschied sich sehr stark von den beiden anderen Reifegruppen, die vergleichbar abschnitten und hinsichtlich der Qualitätskennwerte über einen längeren Zeitraum persistent blieben. Innerhalb aller drei Reifegruppen trat eine starke Variabilität auf, die zu unerwarteten Überlappungen führte. Die Ergebnisse zeigen, dass die gegenwärtige Zuordnung von Lp-Sorten zu den Reifegruppen unscharf ist und durch zusätzliche Erhebungen bzw. Analysen im Zeitraum der Wertprüfung verbessert werden sollte. Dies könnte zu einer verbesserten Auswahl von Lp-Sorten für Grünlandmischungen und in weiterer Folge zur Erhöhung der Futterqualität führen.

Schlagworte: Grünlandarten, Englisches Raygras, Sorten, Reifegruppen, Ausdauer

1. Introduction

For grassland farmers, the efficient use of farm internal resources, such as organic manure and home-grown forage, are the key to a sustainable and successful management. To improve the quality of home-grown forage from meadows and pastures, different strategies have been developed, among others the establishment and renovation of grassland by over-seeding with high-quality seed mixtures are of great importance. Austrian seed mixtures for grassland are containing well-tested cultivars of numerous forage grasses and legumes (Pötsch et al., 2007; Krautzer et al., 2013). *Lolium perenne* L. (Lp) is one of the most common grasses used in seed mixtures for meadows and pastures all over Europe, and there is a huge number of cultivars with different quality characteristics available (Suter et al., 2006; Krautzer et al., 2013; Burns et al., 2015; McDonagh et al., 2015). The selection of cultivars for seed mixtures depends not only on the site conditions, type of grassland management (utilization frequency, and fertilization intensity), but also on the intended purpose (e.g., establishment or over-seeding, meadow or pasture). Lp cultivars are classified into early, medium, and late heading groups (based on the heading dates); however, early heading cultivars are not necessarily also early maturing. It has become very common to use a set of differently heading Lp cultivars for grassland seed mixtures to provide a larger harvest window and to reduce the risk of unfavorable weather conditions, which in mountainous regions very often occur during the harvest time of the first growth.

There is still little information available on the variation of the quality parameters between and within these heading groups so far. The objectives of our project therefore were (i) to illustrate the dynamics of the quality parameters during the first growth, (ii) to identify the variation between the heading groups, and (iii) to determine the optimal harvesting time. The findings will both support the selection of suitable Lp cultivars for seed mixtures under changing environmental conditions and provide grassland farmers with useful information concerning forage quality as well (Parsons et al., 2011; Reheul et al., 2013; Blackmore et al., 2015; Krautzer and Graiss, 2015).

2. Materials and methods

After the official variety testing period, which in Austria for Lp is lasting 3 years and is following the guidelines of the Bundesamt für Ernährungssicherheit (2015), we harvested 39 cultivars of Lp in weekly intervals during the first growth. The tested cultivars were assigned to three heading groups based on the criterion of ear emergence, which follows a nine-part scale (1 = very early to 9 = very late). Cultivars with values from 1 to 3.5 were clustered to the early heading group (n = 12; 8 diploid and 4 tetraploid), those with values from 4 to 6 ended up in the intermediate heading group (n = 14; 6 diploid and 8 tetraploid), and those with values from 7 to 9 represented the late heading group (n = 13; 7 diploid and 6 tetraploid). Such three-part systems are implemented in most European countries, where variety testing experiments are carried out, but there are also two-part systems existing, like in Switzerland, with an early to intermediate early heading group and an intermediate late to late heading group (Suter et al., 2006). The field experiment was conducted at the Federal Research and Education Centre Raumberg-Gumpenstein, Austria (47°29'40"N and 14°06'11"E, 700 m a.s.l.) in the year 2010 with a single plot size of 8.2 m² and four replicates for each of the tested cultivars. The fertilization level in this experiment was 50 kg nitrogen per ha and growth, applied as ammonium nitrate. The soil type is a Cambisol formed from various crystalline rocks, providing sufficient nutrient content according to the Austrian guidelines for an appropriated fertilization (BML-FUW, 2006). The site shows an average annual precipitation of 1,056 mm and a long-term mean annual air temperature of 8.2 °C for the climatological reference period of 1981–2010. The weather conditions in 2010 were ordinary with a well-distributed precipitation of 988 mm and an average annual temperature of 7.7 °C. Yield (DM), crude protein content (CP; VDLUFA, 1976), digestibility of organic matter (dOM; Tilley and Terry, 1963; Resch, 2007), and energy concentration (NEL; GfE, 2001) were determined to illustrate the variability between and within the heading groups. Analyses of variance (ANOVA) were performed with the software package SPSS version 22.0 (IBM®SPSS®Statistics), followed by a multiple range test (Bonferroni post hoc test) using a significance level of $p < 0.05$.

3. Results and discussion

A high level of self-supply with energy and protein has become an important issue in European agriculture, and therefore, there is an increasing interest to improve the forage quality on grassland farms (Pötsch and Lüscher, 2014; Weichselbaum et al., 2016). This strategy reduces the use of farm-external substrates, such as mineral fertilizers or concentrates, which is

cost-saving and environmentally friendly as well. Our results clearly confirm the decreasing protein concentration with belated harvest time during the first growth, showing a linear mean drop of 15 g CP kg^{-1} DM per week for all three heading groups (Figure 1). On an average, the late heading Lp cultivars performed best, followed by the intermediate heading cultivars, and by the early heading group with significantly lower CP concentrations at most of the sampling dates. This result is in contrast to the findings of Burns et al. (2013), who found no significant differences in CP concentrations between the heading groups of Lp cultivars, assuming that the relatively high level of N-fertilization was masking any differences (Binnie et al., 2001). A concentration of 150 g CP kg^{-1} DM, which is at least required for high-yielding cows, was achieved on 14th of May for the early heading group, on 17th of May for the intermediate heading group, and again 3 days later on 20th of May for the late heading group.

Even though there seems to be a clear differentiation between the three groups, a strong variation within the groups can be noticed with some remarkable and unexpected overlapping. Two cultivars of the early heading group, for example, showed much higher CP concentrations that were comparable with those of the late heading group (data not shown here). This finding could also be used to select early heading cultivars providing good winter hardiness and high forage quality as well. It is questionable, whether the assignment to the heading groups based on the visual evaluation is accurate, as it is well known that identifying and quantifying the similarity of varieties of Lp presents a complex problem (Roldán-Ruiz et al., 2001; Ullmann et al., 2013). Feuerstein (2013) faced the challenge in the phenological evaluation of forage grasses and demonstrated a great variation even within apparently homogenous groups. In general, early heading cultivars are classified more accurate than late heading ones, which are mostly assigned too early. This author also referred to the mean stage by count (MSC) method, which outmatches the current system that is widely identical with the BBCH-scheme (Moore et al., 1991). Salama et al. (2009) presented the NMI8 (new maturity index 8), a simple and less time-consuming method for quantifying the phenological development of Lp. This index, expressed as percentage of tillers beginning the reproductive stage, showed comparable correlations to the yield and quality parameters as the MSC.

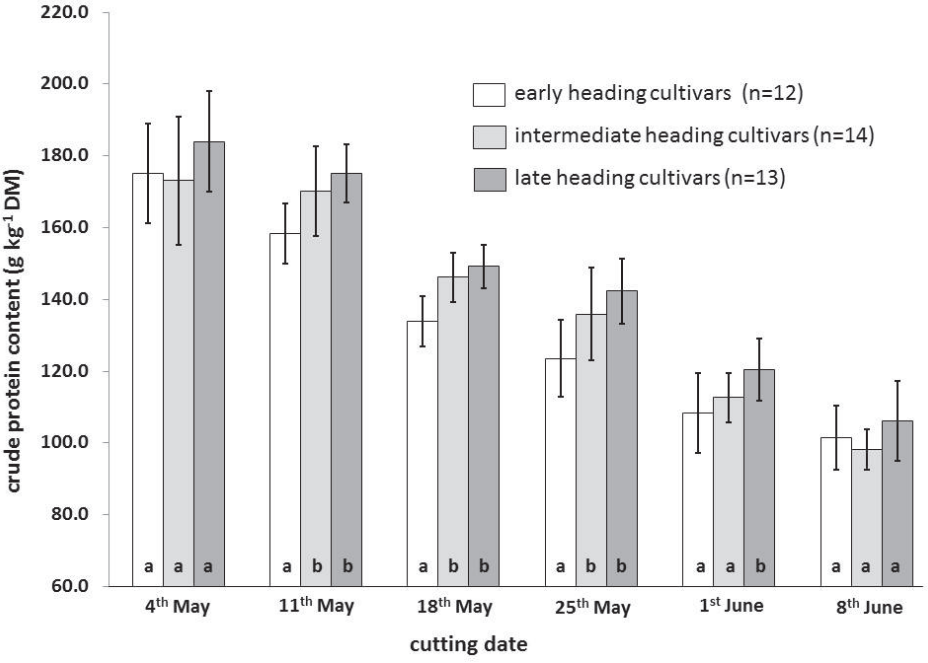

Figure 1. Crude protein content of Lp cultivars in the course of the first growth (different letters indicate a significant difference ($p < 0.05$) between the heading groups at the respective cutting date).

Abbildung 1. Rohproteingehalt von Lp-Sorten im Verlauf des ersten Aufwuchses (unterschiedliche Buchstaben zeigen einen signifikanten Unterschied ($p < 0.05$) zwischen den Reifegruppen beim jeweiligen Schnitttermin).

For farmers, of course, not only high nutrient concentrations are important, but also sufficient yields. Whereas the forage quality decreased during the course of growing period, yield showed an opposed development (Table 1). In all heading groups, the DM yield steadily increased from the first sampling in May to the last one in June. The intermediate and late heading cultivars performed very similar, whereas the early heading cultivars showed a significantly accelerated productivity with a clear time shift, which is in accordance with the results of Laidlaw (2005) and Feuerstein (2013).

To find out the optimal harvest date in grassland will, therefore, always be some compromise between high forage quality and sufficient quantity. But, concerning the occurring difficulties and risks with unfavorable weather conditions, a more resilient dynamic of forage quality can be of great advantage. In this context, intermediate and late heading cultivars offer more flexibility and provide a larger time span for forage quality, but at a significant lower yield level than the early heading group.

The dynamic of dOM during the first growth was following a polynomial function with a clear shift between the three heading groups (Figure 2). In the early heading group, the maximal dOM was achieved on 18th of May with a decrease of 3% per week afterward, whereas the highest dOM of both other groups was obtained 7 and 11 days later, remaining at a high level for another week. Again, some early heading cultivars performed very similar to the intermediate and late heading groups, providing sufficient values of dOM compared with those of other studies (Smit et al., 2005a; Chaves et al., 2006; Wims et al., 2012). The energy concentration (expressed as MJ NEL kg^{-1} DM) is strongly linked with dOM, and therefore, the dynamics during the observation period were similar, but with a lower variation between the three heading groups, which was caused by a high standard deviation (Table 2). Both dOM and energy concentration were on a high level, demonstrating the high quality of Lp, which is an indispensable species for grassland management (Smit et al., 2005b; Humphreys et al., 2010; Sampoux, 2011).

For farmers, not only high forage quality, but also sufficient yield is of great importance. Our results indicate that there is a relatively small time span to achieve high forage quality with early heading Lp cultivars in combination with high yield in the first growth. By contrast, intermediate and late heading Lp cultivars performed much more resilient and provided a later and extended time slot of about 10–12 days for high forage quality and sufficient yield. Again, this is of great relevancy for regions with unstable and frequently changing weather conditions, where it is still a great challenge to gain the required level of forage quality.

Table 1. Yield dynamic of Lp cultivars during the course of the first growth (different letters indicate a significant difference ($p < 0.05$) between the heading groups at the respective cutting date).
Tabelle 1. Ertragsdynamik von Lp-Sorten im Verlauf des ersten Aufwuchses (unterschiedliche Buchstaben zeigen einen signifikanten Unterschied ($p < 0.05$) zwischen den Reifegruppen beim jeweiligen Schnitttermin).

dt DM ha^{-1}	4th May	11th May	18th May	25th May	1st June	8th June
early heading cultivars (n=12)	9.90[a]	18.60[a]	25.17[a]	29.86[a]	32.94[a]	41.47[a]
intermediate heading cultivars (n=14)	7.69[b]	12.44[b]	18.88[b]	20.71[b]	27.33[b]	38.71[a]
late heading cultivars (n=13)	5.86[c]	12.11[b]	16.78[b]	19.78[b]	24.60[b]	34.12[b]

Table 2. Energy concentration of Lp-cultivars during the course of the first growth (different letters indicate a significant difference ($p < 0.05$) between the heading groups at the respective cutting date).
Tabelle 2. Energiekonzentration von Lp-Sorten im Verlauf des ersten Aufwuchses (unterschiedliche Buchstaben zeigen einen signifikanten Unterschied ($p < 0.05$) zwischen den Reifegruppen beim jeweiligen Schnitttermin).

MJ NEL kg^{-1} DM	4th May	11th May	18th May	25th May	1st June	8th June
early heading cultivars (n=12)	6.82[a]	7.12[a]	7.22[a]	7.13[a]	6.83[a]	6.60[a]
intermediate heading cultivars (n=14)	6.40[b]	6.85[ab]	7.07[a]	7.22[a]	7.04[a]	6.86[ab]
late heading cultivars (n=13)	6.22[b]	6.68[b]	7.06[a]	7.16[a]	7.14[a]	7.02[b]

* MegaJoule Net Energy Lactation

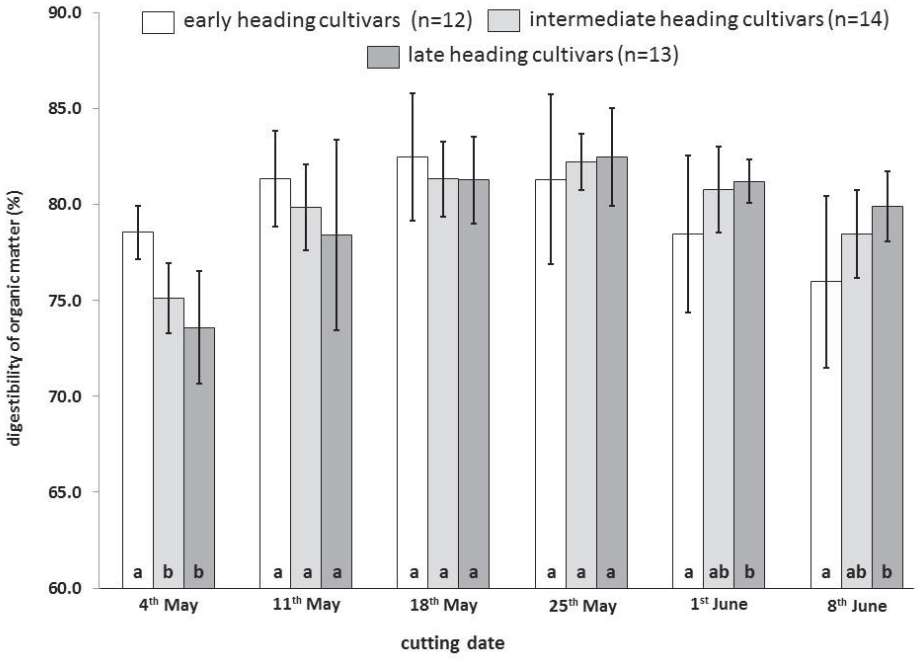

Figure 2. Digestibility of organic matter of Lp cultivars in the course of the first growth (different letters indicate a significant difference ($p < 0.05$) between the heading groups at the respective cutting date).
Abbildung 2. Verdaulichkeit der organischen Substanz von Lp-Sorten im Verlauf des ersten Aufwuchses (unterschiedliche Buchstaben zeigen einen signifikanten Unterschied ($p < 0.05$) zwischen den Reifegruppen beim jeweiligen Schnitttermin).

Table 3 is summing up the overall results of the ANOVA in the course of the first growth for yield, CP, dOM, and NEL, including the heading group, harvest date, and the level of ploidy as the main factors. A significant impact of the heading group on yield and CP but not on dOM and NEL was determined. The ploidy level of the cultivars, which in most of the heading groups was well balanced, had no significant effect on the tested variables, whereas the harvest date significantly influenced all parameters. The endurance tests indicate that new Lp breedings have successfully been selected for better winter hardiness, and therefore, the previous requirement to use 50% diploid and 50% tetraploid cultivars for the late heading group was nullified in some countries (Fisch, 2013).

Table 3. Summarized ANOVA results for yield and selected parameters of forage quality of Lp cultivars assigned to early, intermediate and late heading groups, ploidy level (diploid and tetraploid) and six weekly harvest dates (from 4th of May to 8th of June).
Tabelle 3. Zusammengefasste, varianzanalytische Ergebnisse für Ertrag und ausgewählte Kennwerte zur Futterqualität von Lp-Sorten der frühen, mittleren und späten Reifegruppe, zweier Ploidiestufen (diploid und tetraploid) und sechs Ernteterminen im Wochenabstand (vom 4. Mai bis 8. Juni).

	dependent variable			
	yield [dt DM ha^{-1}]	CP [g kg^{-1} DM]	dOM [%]	NEL [MJ kg^{-1} DM]
heading group (hg)	sign.	sign.	n.s.	n.s.
ploidy level (pl)	n.s.	n.s.	n.s.	n.s.
harvest date (hd)	sign.	sign.	sign.	sign.
hg × hd	sign.	n.s.	sign.	sign.
hg × pl	n.s.	n.s.	n.s.	n.s.
hd × pl	n.s.	n.s	n.s.	n.s.
R^2	*0.93*	*0.89*	*0.49*	*0.41*

Significance level $p < 0.05$

4. Conclusion

As a consequence of the current findings it should be considered to use only two heading groups for Lp cultivars in future, namely early heading and late heading ones. As there is a strong variability of forage quality and also within the heading groups of Lp cultivars, more specific information about these quality characteristics is desirable. There is an ongoing discussion in Austria to implement more detailed recordings and analyses during the official, 3 years lasting variety testing procedure. Our findings also underline the importance of dynamic investigations, which provide essential further information (Swieter et al., 2012). As demonstrated, already established experiments can additionally be used at reasonable costs. All these strategies should finally raise the reliability of the selection of Lp cultivars for grassland seed mixtures.

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