THE RELATION OF COMPRESSED HEIGHT TO ALFALFA (*MEDICAGO SATIVA* L.) DRY MATTER YIELD*

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We investigated the possibility of measuring compressed height with a rising-plate meter to predict the yield of alfalfa stands and its suitability for alfalfa height measurement. Data were collected in a randomised block experiment with six semi-erect germplasms in four replications. Compressed height provided the real estimate of alfalfa height with comparable variability as individual alfalfa plants measuring. We recorded a similar precision of alfalfa yield prediction as with other disc instruments on alfalfa stands or on pastures where the use of a rising-plate meter is often recommended. The effect of germplasm on the accuracy of yield estimation was not significant, indicating suitability of this method for all semi-erect germplasms. The main factor decreasing yield estimation accuracy was the level of alfalfa stand lodging. If lodging does not occur, compressed height measured by a rising-plate meter seems to be a good and well-standardised method for evaluating stand heights and is thus suitable for field experiments as well as for farm use.

alfalfa; stand height; compressed height; rising-plate meter; yield estimate

INTRODUCTION

Breeders as well as researchers consider the height of alfalfa stands as an important feature connected with other agronomic traits (Riday, Brummer, 2002; Radović et al., 2003; Katić et al., 2004). The height is observed in different development stages commonly from the first bud stage. To evaluate the rate of regeneration in the spring as well as after cuts, alfalfa height measurement could be used.

One of the methods for evaluating stand heights is a rising-plate meter (RPM). The RPM is a simple instrument recommended by Castle (1976) for estimating herbage yield on grasslands based on compressed height (CH). The RPM parameters are: diameter 0.3 m; area 0.07 m^2 and weight 0.2 kg. Recently, RPM has often been used on pastures to determine grazing intensity (Pavlů et al., 2004) and to describe the small-scale sward structure of both pastures (Correll et al., 2003) and meadows (Hejcman et al., 2005).

The height of a stand is often highly correlated with standing aboveground biomass (O'Donovan et al., 2002), so the height can be a good forage yield predictor. The standard process for assessing forage mass is to clip and weigh the forage. This direct method requires a great effort and it is expensive to collect enough samples to represent a stand accurately (Sanderson et al., 2001). Griggs and Stringer (1988) investigated alfalfa yield estimation using stand height and a disk technique in week intervals over regrowth periods. Stages were not determined in this study. Two special disk instruments were used: diameter 0.5 m; area 0.2 m^2; disk weight 0.96 kg (DH) or 1.76 kg (HDH). Compressed height measured by the disks was more correlated with the yield than uncompressed stand height. Indirect methods, such as the use of a DH, HDH, RPM and sward stick, were developed to enable fast and non-destructive yield estimation. Results from pastures in the north-east of the USA indicate a calibration error in using the RPM of about 10% of pasture yield (Rayburn, Rayburn, 1998; Unruh, Fick, 1998). It was concluded that a 10% error is acceptable for farm use. Correll et al. (2003) related dry matter yield (DM) with CH by using linear regression. The r^2-values were always above 0.90 and the coefficient of variation of the standard error varied from 0.019 to 0.32; this is considered to be an acceptable range for regression calculated in order to assign herbage masses to measured sward heights (Virkajärvi, 1999).

Sanderson et al. (2001) compared three indirect methods for measuring forage mass on pastures in Pennsylvania, Maryland and West Virginia. They used residual standard deviation (RSD, a synonym of standard error of prediction) as an estimation accuracy parameter. RSD ranged from 26% (percentage of mean forage mass) for the rising-plate and 33% for the capacitance meter. Therefore, they regard these methods to be as not accurate or precise. O'Donovan et al. (2002) compared four methods of herbage mass estimation. Results show a similar and relatively acceptable accuracy of RPM. The capacitance meter method was the most inaccurate predictor of all methods used.

The utilization of the RPM was never investigated to assess alfalfa stand heights and to predict forage yield. The aim of this paper was therefore to answer the following

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question: can an RPM be used to measure alfalfa stand heights and to estimate alfalfa stand yield according to measured compressed height?

MATERIALS AND METHODS

To test the utilization of the RPM, we used a running experiment aimed at comparing 6 semi-erected germplasms of *Medicago sativa* L. (variety Jarka, candivar ŽE XLI, ŽE XLII, ŽE XLV, ŽE IL, ŽE L). The experiment was arranged in completely randomised blocks and CH (compressed height) measurements were performed in four replications.

In the period of our investigation in 2004, the alfalfa stand was in the second growth year. CH measurement was repeatedly realized from the late vegetative to the late flowering stage in the first cut (Table 1) – stages of development were according to Fick and Mueller (1989). To determine dry matter (DM) yields, biomass was clipped in height intervals of 4 cm in the area where the CH was measured.

We used linear regression analysis to evaluate the relationship between CH and DM. We performed two types of regressions: individual stages analysed separately to determine differences in CH predictive values during alfalfa development, and all stages together. Repeated ANOVA was used to detect CH and DM differences among individual stages, germplasms, and their interactions. One-way ANOVA was used to identify RSD differences among germplasms, and developmental stages. All analyses were carried out in the STATISTICA (ver. 6.0) program.

Table 1. Developmental stages and dates of data collection. Codes of stages are after to Fick and Mueller (1989)

Developmental stages	Sampling dates	Code
Late vegetative	3 May	2
First bud	12 May	3
Late bud	21 May	4
First flowering	31 May	5
Late flowering	9 June	6

RESULTS AND DISCUSSION

The values of CH and DM in the different stages are shown in Table 2. There were significant differences among the stages in height as well as in DM yields. Significant differences among germplasms were not recorded for height and DM yields data. The effect of interaction germplasm*stage was not significant (Table 3).

DM yield (y) was related to CH (x) using a linear regression equation of the type $y = a + bx$. The regression results of DM yield for particular stages are shown in Table 4. The RSD, as a percentage of the mean DM yields, increased from 17% in the late vegetative stage to 26.7% in the late flowering stage. RSD was 24.1%, if calculated over all stages together. We did not include the germplasm factor in our analyses because the effect of germplasm on RSD was not significant for DM yield.

The obtained results show that the rising-plate meter does not have a high accuracy in alfalfa yield estimating. The error of the estimate according to the equations was about 20% over the stages. Similar results with the RPM on grassland were published by Sanderson et al. (2001), where an RSD of around 25% was obtained. An RSD of over 25% of average DM yields were recorded for uncompressed stand height, over 20% for compressed height measured with HDH, and around 15% for compressed height measured with DH in an experiment by Griggs and Stringer (1988). Rayburn and Rayburn (1998) and Unruh and Fick (1998) regard a level of error of about 10% of pasture yield with a plate meter as acceptable for use. The obtained $R^2 = 0.69$ in linear regression over the stages corresponded with the result of Virkajärvi (2004). The recorded R^2 in his experiment was 0.61 for yield prediction with a RPM on a pasture. Using an RPM for yield prediction was criticised by Sanderson et al. (2001), who recorded a value of 0.32 for R^2 only. O'Donovan et al. (2002), on the other hand, revealed an extremely high R^2 of 0.94 and 0.92 for the RPM and sward stick, respectively. Griggs and Stringer (1988) obtained R^2 values of 0.79–0.87, 0.90 and 0.91–0.94 for uncompressed stand height and compressed height measured by HDH and DH, respectively. The accuracy of yield estimation based on CH in this study was in accordance with our results. Radović et al. (2003) investigated the relationship between height

Table 2. The main statistic characteristics of height and DM yield (SD = standard deviation, CV = coefficient of variation, $HG_{0,01}$ = Tukey homogenous group, differences significant at 0.01 probability value)

Stage	Compressed height (m)				DM yield (kg ha^{-1})			
	mean	SD	CV	$HG_{0,01}$	mean	SD	CV	$HG_{0,01}$
2	0.27	0.0410	15.1	a	3729	634	17.0	a
3	0.39	0.0475	12.3	b	4483	834	18.6	a
4	0.43	0.0731	16.9	b	6234	1625	26.1	b
5	0.51	0.0798	15.6	c	6824	1688	24.7	b
6	0.66	0.0884	13.4	d	9321	3024	32.4	c
Over stages	–	–	14.7		–	–	23.8	

Table 3. Results of repeated ANOVA analyses of compressed heights (CH) and dry matter (DM) yields data

	Factor	Df	*F*-ratio	*P*
CH	developmental stage	4	150.9	0.0000
	germplasm	5	1.7	0.1761
	stage*germplasm	20	0.6	0.8805
DM	developmental stage	4	38.20	0.0000
	germplasm	5	0.23	0.9458
	stage*germplasm	20	0.72	0.7946

Table 4. Relating alfalfa yield (y, kg DM ha^{-1}) and compressed height of stand (x, m) over main development stages (linear regression, $y = a + bx$), RSD = residual standard deviation, % = RSD percentage of mean DM yield

Stage	*a*	*b*	r^2	*F*-ratio	*P*-value	RSD	%	Df
Late vegetative	2888.14	31.01	0.0401	0.92	0.3487	635	17.0	23
Early bud	1872.14	67.75	0.1488	3.84	0.0627	786	17.5	23
Late bud	–1620.07	182.13	0.6706	49.18	0.0000	954	15.3	23
Early flowering	834.166	117.064	0.3058	9.69	0.0051	1438	21.1	23
Late flowering	–4105.21	203.037	0.3521	11.95	0.0022	2489	26.7	23
Over stages	–564.937	147.805	0.6853	256.85	0.0000	1480	24.1	119

and DM yield of alfalfa progenies measured on individual plants, and obtained an R^2 value of 0.53. We revealed a slightly higher correlation in our experiment.

There are differences in accuracy of yield prediction among stages. The accuracy of DM yield estimation is on a relatively acceptable level with RSD 18.4% until the late bud stage. Accuracy substantially decreased in later stages with RSD ranging from 21.1 to 26.7 (Table 4). There were no significant differences in accuracy among germplasms or stages. In later developmental stages, an increasing level of stand lodging probably caused a decrease in accuracy. To reveal the effect of lodging on the precision of yield estimation, we performed measuring in another field experiment, where no-lodging alfalfa stand in the third cut, the late flower stage, occurred (Hakl, unpublished). RSD values were around 17% for DM yield there, indicating that the level of stand lodging is a more decisive factor for yield estimation accuracy than the stage of development. Griggs and Stringer (1988) omitted lodged alfalfa stands, hence the effect of lodging cannot be discussed in this study. The CV for CH varied from 12.3 to 16.9% in individual stages, and the average over the stages was 14.7% (Table 2). A similar variability of height measured on spaced plants in harvest time (CV = 8.1–13.9%) was published by Radović et al. (2003). They obtained a higher variability of DM yield (CV = 19.3–30.3%) than variability of plant height; the same result was recorded also in our study. It is interesting that the CV of compressed height is of approximately the same level over the stages, whereas the CV of yield was increasing.

CONCLUSION

Compressed height measured by a rising-plate meter is a simple and quick in application and is not expensive. We recorded a similar precision of alfalfa yield prediction as with other disc instruments on alfalfa stands or on pastures where the use of a rising-plate meter is often recommended. The main factor decreasing the accuracy of yield estimation was the level of alfalfa stand lodging. If lodging does not occur, compressed height measured by a rising-plate meter seems to be a good and standardised method for evaluating stand heights and is thus suitable for field experiments as well as for farm use.

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Vztah stlačené výšky porostu k výnosu sušiny u vojtěšky seté (*Medicago sativa* L.).

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Cílem práce bylo vyhodnotit vztah stlačené výšky porostu k výnosu sušiny u vojtěšky seté (*Medicago sativa* L.). Zpracovávaná data byla pořízena v probíhajícím experimentu se šesti původy vojtěšky (všechny s typem trsu vzpřímeného až polovzpříměného), uspořádaném ve znáhodněných blocích ve čtyřech opakováních. Stlačená výška, hodnocená talířovým měřidlem, poskytuje reálný odhad výšky porostu s podobnou variabilitou jako v literatuře uváděné hodnocení výšky u individuálních rostlin. Při odhadu výnosu vojtěšky jsme zaznamenali přesnost jako u podobných měřidel na vojtěškových porostech nebo pastvinách, kde je použití talířového měřidla doporučováno. Vliv odrůdy na přesnost odhadu nebyl významný, a metodu lze tedy doporučit pro ostatní vzpřímené a polovzpřímené odrůdy. Hlavní faktor snižující přesnost odhadu výnosu bylo polehání porostu. Pokud není zaznamenáno poléhání, stlačená výška měřená talířovým měřidlem se zdá být vhodnou a jednoduchou metodou pro hodnocení výšky porostu a odhad výnosu a je tedy využitelná pro polní pokusy i zemědělskou praxi.

vojtěška; výška porostu; talířové měřidlo; odhad výnosu

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