Ital. J. Agron., 7, 2, 103-110

The Use of the Grassmeter as a Simplified Method to Estimate Dry Matter Yield on Annual Self-Reseeding Medics and Clovers

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Received: 31 October 2002. Accepted: 10 November 2003.

ABSTRACT

BACKGROUND. The grassmeter non-destructive method was used to estimate dry matter yield (DMY) of 24 annual self-reseeding legumes. The possibility was evaluated of using the grassmeter as an alternative to conventional destructive quadrats for large field plot experiments.

METHODS. The linear regressions between sward height measured by the grassmeter and DMY were analysed. Three types of regression equations were calculated: (i) 'general', a single equation including the three-year set of height/DMY pairs of data; (ii) 'specific', one regression equation for each species; (iii) 'preliminary', calculated from the data collected in the spring and autumn cuts of the first year.

RESULTS. The 'general' calibration gave a satisfactory estimate of DMY (R^2=0.55). The 'specific' calibration was particularly accurate for *Trifolium brachycalicynum* "Osilo" (R^2=0.88), *T. squarrosum* "Chilivani" (R^2=0.81) and *Medicago polymorpha* "Circle Valley" (R^2=0.81), but not for *M. rugosa* "Sapo" (R^2=0.22) and "Paraponto" (R^2=0.26). The 'preliminary' calibration, which was based only on the destructive assessment of DMY at the first cut, provided reliable estimates of DMY until the sward conditions, namely cover rate and weeds, were comparable to those of the calibration period. The coefficient of variation of the DMY estimate based on the grassmeter 'general' calibration was about 10% lower than that of the DMY measured with conventional quadrats.

CONCLUSIONS. Results suggest that the grassmeter could effectively replace destructive measurements for estimating the DMY of annual self-reseeding legumes, thus reducing labour requirements and number of samples to be processed, or increasing, when needed, the number of accessions to compare and hence the inference of the experiment.

Key-words: annual medics, annual clovers, canopy height, grassmeter, dry matter yield.

INTRODUCTION

Simplified and fast techniques to estimate forage yield are useful for preliminary comparison of forage species in small plots or for data evaluation leading to sound management of large pasture areas (Gonzales et al., 1990). Conventional destructive methods to assess aboveground phytomass yield are based on herbage cutting and harvesting of sample areas. However, they are time and labour consuming, thereby limiting the number of data to be compared. Similar problems occur during the evaluation of large-sized pasture yields, which require a high number of destructive samples to obtain sufficient accuracy of the estimate (Green et al., 1989). Several authors have shown that the time required for destructive methods, i.e. quadrats or ground level samples, allows a number of samples to be collected which is often insufficient to achieve the desired accuracy (Frame and Hunt, 1971; Gonzales et al., 1990).

In forage crops, several non-destructive methods may be used for experimental purposes in order to estimate the aboveground phytomass yield (Frame, 1993). Apart from the visual estimate empirical method (Campbell and Arnold, 1973) and the use of ultrasounds (Hutchings, 1991), sward height can be measured with different devices such as the "HFRO sward stick" (Bircham, 1981; Bartham, 1985; Franca et al., 1995), various types of plates or disc meters (also known as grassmeter, or herbomètre in French), which measure the canopy height when compressed by a disk or a calibrated plate (Bransby et al., 1977; Mac Intyre, 1978; Earle and McGowan, 1979) and the "capacitance meter" or its evolution, the "pasture probe" (Vickery et al., 1980; Vickery and Nicol, 1982; Greathead et al., 1987).

This study aims to check the possibility of using the simplified "plate meter" method (hereinafter referred to as "grassmeter") to compare accessions of self-reseeding annual legumes. The method is an alternative to destructive methods, as can measure yield differences among accessions in low yielding periods, when cutting is not possible or does not allow comparison of accessions with acceptable accuracy.

MATERIALS AND METHODS

The trial was carried out between autumn 1990 and spring 1993, on the experimental farm of the Istituto Zootecnico e Caseario per la Sardegna in Bonassai (Sassari), located on the Nurra plain (north-west Sardinia).

The climate of the area is typically Mediterranean, with total annual rainfall of 547 mm (peak in autumn) and mean temperature of 16.2 °C (Figure 1). From September to August, in the three years examined, 682, 620 and 526 mm of rain were recorded, respectively (Figure 2). In the first year, rainfall distribution was relatively favourable, especially in spring, with 258 mm in March-May, which was twice that of the corresponding 32-year average, and mean temperatures were slightly lower.

In the following year, after a 400 mm autumn rainfall, only 85 mm followed in spring, with two long dry periods in December and May.

The third year was characterized by a rainy October (200 mm of rain), dry November (25 mm) and no rains in January. Spring rains were of intermediate magnitude with respect to previous years. In autumn 1993, when the last field trials were done, 362 mm of rain were recorded.

The experiment had been designed to cut the plot biomass when grassmeter height reached 8 cm, weed rate was lower than 40% and cover rate higher than 60%. Further details on the soil characteristics of the site, materials used and experimental design were described by Fara et al. (1997).

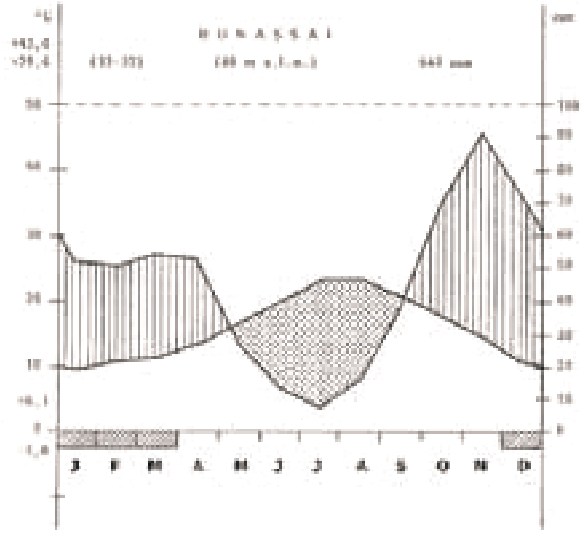

Figure 1. Climate diagram for the experimental site (Walter and Lieth, 1967).

The grassmeter used for this study was first described by Earle and McGowan (1979), and built and modified at the Department of Agricultural Sciences and Plant Genetics of the University of Sassari. It is made up of a square plexiglas plate (30x30 cm x 0.3 cm thick) with a central hole, 3 cm in diameter, where a PVC 50 cm-high cylindrical cursor is welded. The plate + cursor system has a standard weight of 430 g and slides along a 120-cm high graduated aluminium stick which enables canopy height to be recorded at about 50 cm from the ground. At the stick base a 5 cm diameter plastic disc is welded to secure plate stability. Surveys were conducted with the grassmeter placed vertically on the sward; the plate was lifted and then

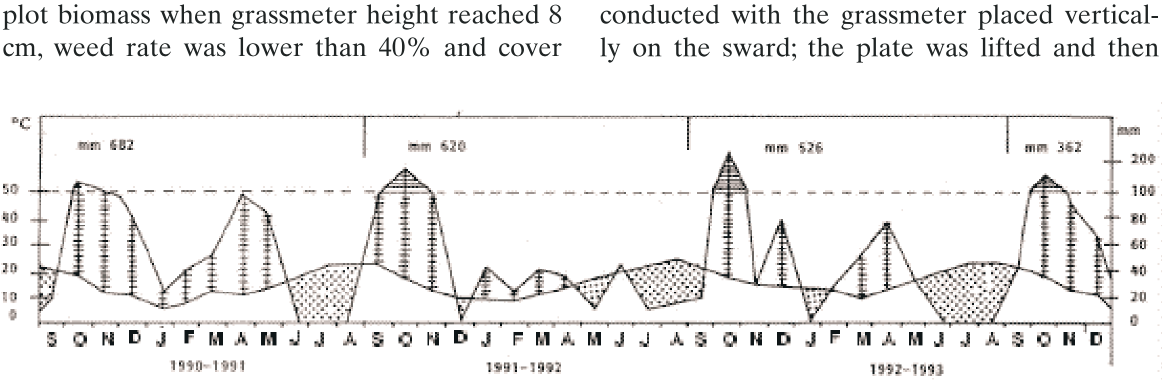

Figure 2. Monthly temperature (°C) and rainfall (mm) during the 3-year trial.

Table 1. Estimate of the parameters of the linear regressions between height (cm, independent variable) and dry matter yield (t ha^{-1}, dependent variable) of the legume accessions that persisted for three years.
n-2 = d.f.; r = regression coefficient; a = intercept; b = correlation coefficient;
P = error probability (NS = >0.05; * <0.05; ** <0.01; * <0.001).**

Specie	Accession	n-2	r	a	b	P	height range
General regression (all species)		166	0.74	0.32	0.14	***	1.5 ÷ 55.0
All medics regression		57	0.74	0.41	0.15	***	2.0 ÷ 46.5
All clovers regression		107	0.76	0.36	0.13	***	1.5 ÷ 55.0
Specific regressions							
Medicago arabica	"IAS"	10	0.79	0.23	0.20	**	2.0 ÷ 37.3
Medicago polymorpha	"Circle Valley"	9	0.90	-0.56	0.19	***	2.6 ÷ 46.5
Medicago rugosa	"Paraponto"	10	0.47	1.32	0.06	NS	3.9 ÷ 28.3
Medicago rugosa	"Sapo"	10	0.51	0.96	0.10	NS	2.5 ÷ 39.8
Medicago truncatula	"Paraggio"	10	0.73	1.64	0.12	*	2.6 ÷ 46.5
Trifolium brachycalycinum	"Funtana Bona"	16	0.85	-0.27	0.17	***	1.7 ÷ 38.3
Trifolium brachycalycinum	"Osilo"	16	0.94	0.23	0.10	***	1.5 ÷ 40.8
Trifolium brachycalycinum	"Pranusanguni"	16	0.70	0.02	0.15	**	2.0 ÷ 32.0
Trifolium brachycalycinum	"Rosedale"	13	0.66	-0.59	0.19	**	2.0 ÷ 25.0
Trifolium yanninicum	"Meteora"	9	0.61	0.84	0.12	*	2.0 ÷ 37.7
Trifolium yanninicum	"Larissa"	12	0.73	0.83	0.11	**	1.5 ÷ 35.0
Trifolium squarrosum	"Chilivani"	13	0.90	0.72	0.11	**	1.7 ÷ 55.0

slowly lowered down so as to record the grass height at stick site where the plate weight was in equilibrium with the vegetation support.

The DMY was estimated by the destructive method with the procedures reported by Fara et al. (1997). Ten height measurements were taken on different areas of each plot.

The relationship between grassmeter height and dry matter yield (DMY), evaluated with destructive methods, was analysed through linear regression analysis, considering DMY as dependent variable and height (average of ten surveys per plot) as independent. Regression equations were calculated for each species and, after checking the homogeneity of error variance and regression parameters, within genus and for all species. Linear regression equations were used to calibrate the grassmeter and for the indirect DMY estimate, even when destructive sampling was not possible. Height differences among accessions were assessed with a two-way analysis of variance procedure.

RESULTS AND DISCUSSION

Grassmeter calibration

The relationship between DMY values (Y, t ha^{-1}) and canopy height (H, cm) relating to all accessions for all cuts in the three-year period (Table 1) resulted in a significant linear regression Y = 0.14.H + 0.32. This was acquired as 'general' calibration line of the grassmeter. Each regression estimated within species was assumed as 'specific' calibration line. The 'general' calibration gave a satisfactory yield estimate. The non-destructive estimate of DMY based on 'specific' calibration was accurate for *Trifolium brachycalycinum* "Osilo", *T. squarrosum* "Chilivani" and *Medicago polymorpha* "Circle Valley" ($R^2 \geq 0.80$). In contrast, 'specific' calibrations estimated for both *M. rugosa* accessions were not significant because of the high error variance (Table 1).

The significant regression coefficients (b) were from 0.10 to 0.20 t ha^{-1} cm^{-1} in the range of 1.5 to 55 cm of sward height (Table 1). Harmoney et al. (1997) found highly significant regression coefficients between raising plate meter and DMY of alfalfa and red clover of from 0.23 to 0.24 t ha^{-1} cm^{-1} with an R^2 ranging from 0.73 to 0.84; Griggs and Stringer (1988), found higher regression coefficients in lucerne (from 1.00 to 1.43 t ha^{-1} cm^{-1}) with $R^2 \geq 0.90$ ($P<0.01$). The relatively low regression coefficients of annual self-reseeding legumes can be attributed to a relatively low sward density.

The relationship between grassmeter height and autumn/spring DMY in the first year was analysed for the 12 accessions which persisted for the three-year period, with the aim of obtaining an effective calibration of the grassmeter from the cuts made at the beginning of the experiment and test the reliability of the regression model for the following periods (Figure 3). The resulting regression line (Y = 0.15H – 0.24) revealed a sufficient estimate accuracy (R^2 = 0.64**) and was considered as 'preliminary' calibration line of the grassmeter.

Considering the total DMY in the three years, the relative differences among accessions, tested in terms of grassmeter height, were similar to those obtained using the DMY measured with destructive methods (Table 2), with the exception of *M. arabica* "IAS" and *T. brachycalycinum* "Osilo". This result can be explained by the different growth habit of both accessions with respect to other homologous species: *M. arabica* "IAS" had a more prostrate habit than the other medics, *T. brachycalycinum* "Osilo" had a more upright habit than the other accessions of the same species. This is also confirmed by the regression coefficients of *M. arabica* "IAS" (0.20 t ha^{-1} cm^{-1}), which was significantly higher than that of *T. brachycalicinum* "Osilo" (0.10 t ha^{-1} cm^{-1}).

The grassmeter height provided detailed information on the biomass build-up dynamics and differences between accessions, even within species. For example, the local ecotype *T. brachycalycinum* "Pranusanguni" showed slower winter growth than "Osilo" and "Funtana Bona", in both the second and third year of the trial (Figure 4). Moreover, the spring yield of *T. brachycalycinum* "Osilo", which was lower than

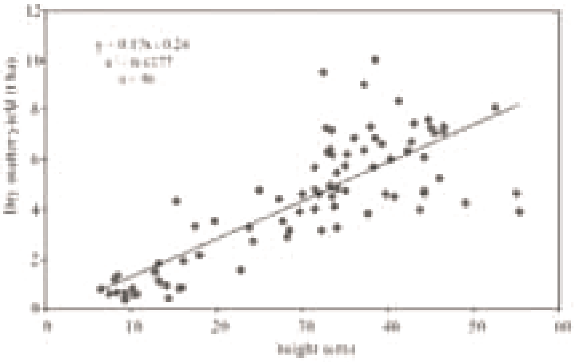

Figure 3. Linear regression between spring and autumn canopy height (cm) and DMY (t ha^{-1}) in the first year (preliminary calibration) for the 12 accessions persisting for 3 years.

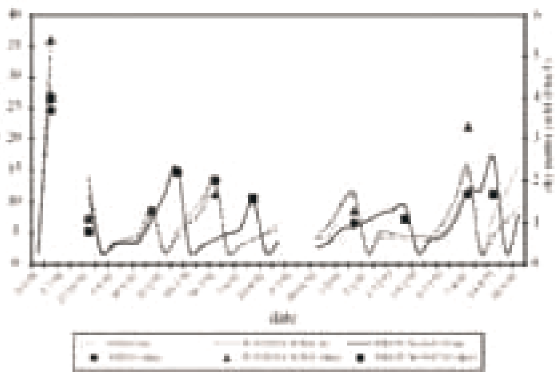

Figure 4. Comparison between three local *T. brachycalycinum* accessions for herbage height (cm) measured with the grassmeter, and DMY estimated with the destructive method at the cutting dates, during the 3-year trial.

Table 2. Average 3-year total canopy height (cm) and DMY (t ha^{-1}), estimated using destructive and non-destructive methods ('general', 'specific' and 'preliminary' calibration of the grassmeter) for the most persistent accessions. CV = coefficient of variation. Means followed by the same letter are not significantly different (P<0.05; Fisher's protected test).

			Total dry matter yield estimate (t ha^{-1})			
		Grassmeter	Destruptive		Non Destruptive	
Species	Accession	height (cm)		general	preliminary	specific
Medicago arabica	"IAS"	60.1 e	13.2 ad	9.7 h	7.1 de	12.9 c
Medicago polymorpha	"Circle Valley"	69.9 de	11.0 be	11.1 fh	8.7 cd	11.0 d
Medicago rugosa	"Paraponto"	63.1 e	9.2 e	10.1 gh	7.6 de	9.1 e
Medicago rugosa	"Sapo"	70.9 de	11.1 be	11.5 eg	8.8 cd	10.9 d
Medicago truncatula	"Paraggio"	87.0 ac	16.7 a	13.5 bd	11.4 ab	17.0 a
Trifolium brachycalycinum	"Funtana Bona"	97.7 a	14.1 ac	15.6 a	11.9 a	15.0 b
Trifolium brachycalycinum	"Osilo"	95.9 a	10.8 de	15.3 a	11.6 ab	11.0 d
Trifolium brachycalycinum	"Pranusanguni"	91.7 ab	14.4 ab	15.1 ab	10.9 ab	13.9 bc
Trifolium brachycalycinum	"Rosedale"	60.8 e	9.2 e	10.1 gh	6.6 e	8.6 e
Trifolium yanninicum	"Meteora"	76.8 cd	11.9 be	12.0 df	9.8 bc	12.6 cd
Trifolium yanninicum	"Larissa"	81.2 bd	10.4 ce	13.0 ce	9.9 bc	13.1 c
Trifolium squarrosum	"Chilivani"	88.6 ab	13.2 ad	14.0 ac	11.0 ab	13.3 bc
C.V. (%)		*8.7*	*17.6*	*7.7*	*11.3*	*8.5*

that of "Funtana Bona" at the spring cut in the first and third year, was not confirmed in terms of grassmeter height, which was very similar for both accessions.

The better distribution within the plot and the higher number of sward height measurements made with the grassmeter resulted in a lower coefficient of variation (10%) than DMY measurements made with destructive quadrats.

Grassmeter heights at cutting

Significant height differences among accessions were evidenced only in four out of the thirteen cutting dates. Only on 14/4/93, were there significant height differences among accessions showing not significantly different DMY, while on the other three dates the results obtained with the grassmeter and destructive methods were similar (Fara et al., 1997).

In spring of the first year, subclovers were significantly shorter than all other legumes. In autumn, only *T. brachycalycinum* (except "Clare"), *M. rugosa* "Sapo" and *M. arabica* "IAS" achieved a sufficient sward height for cutting.

At the end of winter in the second year (25/2/92), medics were earlier, being 2-3 cm higher than most clovers (Table 3). *T. yanninicum* "Larissa" and "Meteora" were not cut in the autumn, in the second and third year, but reached the threshold height early in winter ("Meteora" only in the third year) and spring. In spring of the third year, considering only the accessions which were cut (i.e. those whose height, weed and cover rate met the experimental design requirements), significant differences were recorded only in grassmeter heights, while DMY differences were not significant. The lowest sward height was that of *M. arabica* (about 9 cm), the highest were *T. yanninicum* "Meteora" (20 cm) and *T. brachycalycinum* "Pranusanguni". The drought between February and May 1992 affected medics more than clovers, with medics never achieving threshold cutting height. In the third year, differences between medic and clover heights were negligible when cut at the same time, as frequent cutting induced a prostrate habit in medics.

CONCLUSIONS

The results, obtained in the context of an experiment that had been mainly designed for assessing the DMY of different annual self-reseeding legumes, indicate that the grassmeter is suitable for estimating DMY and seasonal distribution with a non-destructive, fast method. The grassmeter height can be therefore considered a suitable parameter to support grazing management of annual pasture legumes.

The grassmeter allowed a high number of surveys per plot, which contributed to reduce error variance and hence improve the precision of the experiment. The user-friendly application of the grassmeter allows measurement of sward yield dynamics, as a response to environmental and agronomic factors, also during periods when the grass is too short for cutting.

However, the results indicate that the grassmeter should be used with caution to estimate the absolute aboveground phytomass of self-reseeding legumes. The advantages of applicability and reduced intra-plot variability of heights vs. DMY measurements are balanced by the need to compare only accessions characterised by a homogeneous cover structure, without a high proportion of supporting tissues (plants with lignified stems), which would lower the reliability of the height/yield relationship.

In Mediterranean areas and on therophyte swards, application of this method may be constrained by the dynamics of the plant cover structure in response to rapid temperature variations and soil water deficit. This adds to the constraints found by other authors due to season effect and dry matter content (Bransby et al., 1977; Prache et al., 1989; Duru and Bossuet, 1992).

The evaluation of self-reseeding legumes with the grassmeter requires at least some calibration and hence a combination of destructive and non-destructive methods. The calibration equation based on data collected at the beginning of the trial ('preliminary' calibration), seems valid as long as conditions of weeds and cover rates found at the time of calibration are substantially met in other periods and the height range explored is sufficiently wide. Should this not be the case, the calibration should be updated on the basis of new destructive surveys. In the case of plot screenings with a high number of treatments, it is possible to do just one destructive calibration survey and a proportional increase of non-destructive methods. In this case it is always advisable to check the assumption of homogeneity of error variances.

Table 3. Seasonal, annual and 3-year total grassmeter heights (cm) measured before each cut.
NS = not significant; LSD = Least Significant Difference

Species	Accessions	1990/91	1991/92								1992/93						3-years
		Spring	Autumn		Winter			Spring		Total	Autumn	Inv.		Spring		Total	Total
		17/5/91	27/11/91	7/1/92	25/2/92	10/3/92	30/3/92	9/4/92	24/4/92		10/12/92	5/2/93	19/2/93	5/4/93	14/4/93		
Annual medics																	
M. arabica	IAS	32.8	8.0							8.0			10.4		8.8	19.3	60.1
M. murex	ZODIAC S 34	43.7			10.2					10.2							
M. murex	ZODIAC	39.0															
M. orbicularis	IAS	33.3															
M. polymorpha	CIRCLE VALLEY	39.8			10.0					10.0	9.8			10.3		20.1	69.8
M. rugosa	PARAPONTO	25.1			13.3					13.3		11.1			13.6	24.6	63.0
M. rugosa	SAPO	33.3	13.1							13.1	10.2				14.4	24.5	70.9
M. truncatula	PARABINGA	36.2															
M. truncatula	PARAGGIO	43.9			13.3					13.3		14.7			15.1	29.8	87.0
Average		36.3								11.3						23.6	70.1
Subclovers																	
T. brachycalycinum	CLARE	31.4															
T. brachycalycinum	FUNTANA BONA	34.3	13.9		9.3		13.2			36.4		11.5		15.5		27.0	97.7
T. brachycalycinum	OSILO	35.7	12.8		8.0		13.8			34.6		10.9		14.7		25.6	95.9
T. brachycalycinum	PRANUSANGUNI	28.5	11.1			15.3			10.2	36.7			9.4		17.1	26.5	91.7
T. brachycalycinum	ROSEDALE	17.7	10.2		8.7		11.1			30.0				13.3		13.3	60.8
T. subterraneum	DALIAK	12.9															
T. subterraneum	MOUNT BARKER	17.5															
T. yanninicum	LARISSA	33.9		9.3			15.8			25.1			8.3		14.0	22.3	81.3
T. yanninicum	METEORA	34.4						10.4		10.4			12.0		20.0	32.0	76.8
Average		27.4								28.9						24.4	84.0
Other clovers																	
T. alexandrinum	COMMERCIALE	48.4															
T. michelianum	GIORGIA	35.1															
T. michelianum	GIOVY	35.9															
T. resupinatum	COMMERCIALE	45.7															
T. resupinatum	KYAMBRO	40.6															
T. squarrosum	CHILIVANI	45.8				8.8		11.1		19.9		11.7		11.2		22.8	88.6
Average		41.9								19.9						22.8	88.6
LSD ($P < 0,05$)		*7.9*	*NS*			*4.3*	*3.3*	*NS*	*NS*	*4.5*		*NS*	*NS*	*NS*	*4.4*	*8.1*	*17.6*

ACKNOWLEDGEMENTS

We wish to thank Dr. Gianfranco Fara for his valuable collaboration, Mr. Antonello Piga from the Dipartimento di Scienze Agronomiche e Genetica Vegetale Agraria of Sassari, who built the grassmeter used in the trial, Mr. Salvatore Nieddu, Anton Pietro Stangoni, Daniele Dettori and Piero Saba, CNR-ISPAAM, Sezione 'Pascoli Mediterranei', Sassari, in charge of the experimental plots management and sample processing in the laboratory and Dr. Sara Maltoni, for her assistance in the English editing.

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USO DELL'ERBOMETRO COME METODO SEMPLIFICATO PER LA STIMA DELLE PRODUZIONI DI MEDICHE E TRIFOGLI ANNUALI AUTORISEMINANTI

SCOPO. Nel contesto di una sperimentazione finalizzata allo studio dell'adattamento e della persistenza di 24 leguminose foraggere annuali autoriseminanti, è stata verificata la possibilità di impiego dell'erbometro a piatto pesato come metodo semplificato per la stima non distruttiva della produzione di sostanza secca (s.s.), in alternativa a metodi distruttivi.
METODO. È stata analizzata la regressione lineare tra altezza del cotico erboso misurata con il piatto pesato e la produzione di sostanza secca di 24 accessioni coltivate in parcelle sperimentali a densità di semina agronomica. Sono stati calcolati tre tipi di equazioni di regressione: 'generale', basata su tutti i dati di altezza e produzione disponibili nel triennio; 'specifica', ognuna basata sui dati triennali relativi alle singole specie; 'preliminare', ottenuta dai dati relativi al taglio primaverile e autunnale del primo anno dalla semina, per le accessioni che hanno persistito nel triennio di prova.
RISULTATI. La calibrazione 'generale' ha permesso una stima della produzione soddisfacente (R^2=0,55). La calibrazione 'specifica' è risultata precisa per trifoglio brachicalicino "Osilo" (R^2=0,88), trifoglio squarroso "Chilivani" (R^2=0,81) e medica polimorfa "Circle Valley" (R^2=0,81), ma non per la medica rugosa "Paraponto" (R^2=0,26) e "Sapo" (R^2=0,22). La calibrazione 'preliminare' ha permesso una stima attendibile della produzione di s.s. sino a quando le condizioni di ricoprimento ed infestazione delle parcelle erano assimilabili, per infestazione e fittezza, a quelle del periodo di taratura.
La stima non distruttiva della produzione nel triennio, ottenuta attraverso la calibrazione 'generale' dell'erbometro, ha mostrato un coefficiente di variabilità inferiore del 10% rispetto alla misura distruttiva.
CONCLUSIONI. Dai risultati ottenuti è possibile affermare che l'impiego dell'erbometro a piatto pesato può essere efficace, in alternativa ai metodi distruttivi, per i confronti parcellari di numerose accessioni di leguminose annuali autoriseminanti. Con l'erbometro è infatti possibile, mantenendo livelli accettabili di precisione, ridurre notevolmente la manodopera e il numero di campioni da trattare in laboratorio e quindi, a parità di risorse disponibili, aumentare il numero di accessioni da confrontare e quindi l'inferenza della sperimentazione.

Parole chiave: mediche annuali, trifogli annuali, altezza della cotica, erbometro, produzione di sostanza secca.