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Functional analysis of dry matter accumulation in pure artificial meadows

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SUMMARY - The aim of this paper is to assess the possibility of carrying out a functional analysis of dry matter accumulation in two forage crops, cocksfoot (*Dactylis glomerata* L.) and sainfoin (*Onobrychis viciifolia* Scop.), grown as dryland crop in Southern Italy. For each experimental factor examined (species, harvest time, cutting height), the Gompertz's logistical function at 3 parameters: $W\ (t * ha^{-1}) = a * exp\ (-exp^{(b-kt)})$ *was adapted to determine the growth curves of dry matter over time. The function interpolated the data obtained extremely well. The following analysis of variance, univariate and multivariate, carried out on the values of the parameters of curves, allowed the discrimination of the growth trends.*

Key words: *Meadows, dry matter accumulation, Gompertz's logistical function, growth curves.*

RESUME - *"Analyse fonctionnelle de l'accumulation de matière sèche dans les prairies artificielles". Cet étude a le but d'évaluer la possibilité d'effectuer un analyse fonctionnelle du cumul de matière sèche de deux cultures fourragères, la dactyle aggloméré (Dactylis glomerata* L.*) et la mélilot jaune (Onobrychis viciifolia* Scop. *), cultivées sans irrigation. L'expérimentation a été menée dans le Sud de l'Italie. Pour tous les facteurs examinés (espèces, époque et hauteur de fauchage), la fonction logistique de Gompertz avec trois paramètres :*
$W\ (t * ha^{-1}) = a * exp\ (-exp^{(b-kt)})$ *a été adaptée pour déterminer dans le temps les courbes de croissance de la matière sèche. La fonction a très bien interpolée les données expérimentales. La suivante analyse statistique des paramètres des courbes a permis la discrimination des tendances de croissance.*

Mots-clés *: Prés artificiels, cumul de matière sèche, fonction logistique de Gompertz, courbes de croissance.*

Introduction

In some areas of Southern Italy, characterized by a great variability of seasonal weather and by always poorly fertile and deep soils, it is necessary for research to tend towards the identification of the most appropriate forage crops and agronomic techniques.

With the goal of making a contribution to this topic and referring to the results until now obtained, this Institute undertook a study on artificial meadow species submitted to different times and heights of cutting (Maiorana *et al.*, 1995). In this paper, the results of a functional analysis of dry matter accumulation are examined.

The functional method of growth analysis allows us to describe the crops growth in continuous way, adapting logistic mathematical functions or other functions to the original growth data.

From these functions it is possible, therefore, to derive the instantaneous values of the growth indexes (Causton and Venus, 1981; Castrignanò *et al.*, 1987). An important aspect of this method is that it allows the highlighting of the principal growth trend, separating it from the small fluctuations of a casual nature that tend to confuse it.

Materials and methods

The experiment was conducted at Rutigliano (southern Italy), on the Experimental Farm of the Institute, from winter of 1991 till summer of 1995.

Three harvest times (when the sward reached a height of 10, 15, and 20 cm) and two cutting heights (close to the ground and at 5 cm) were compared on two artificial meadow species, the cocksfoot (*Dactylis glomerata*, L.) and the sainfoin (*Onobrychis viciifolia* Scop.), grown as dryland crop.

The analysis of dry matter accumulation has been carried out on the productive results of 1992 trial year.

The experimental design was a split-split-plot with the forage crops as main plot, the harvest times as sub-plot and the cutting heights as sub-sub-plot, with three replications.

The production of green forage was determined for each harvest, excluding the two external rows of plants in all of the plots. Therefore, the dry matter content was determined on a sample of 1000 g of green forage, after oven-drying at a temperature of 105°C till a constant weight.

For the purpose of this study, the dry matter productions obtained in each harvest were added to those of the previous harvests. Moreover, in the treatments with plant cutting at 5 cm of height, within each crop and harvest time, the mean difference between the cutting close to the ground and that at 5 cm was added to the productions of dry matter of the first cutting, so as to be able to take into consideration the amount of plant remained uncut with the 5 cm cutting height.

For each species, harvest time, cutting height and replication, the Gompertz's logistical function at three parameters (Causton and Venus, 1981): $W\ (t * ha^{-1}) = a * \exp\ (-\exp^{(b-kt)})$ was adapted to determine the growth curves of the dry matter over time. *W* represents the dry matter produced, *t* is the time in days from the beginning of growing season (21 and 24 March for cocksfoot and sainfoin, respectively), *a* represents the maximum value of the curve (and therefore, the maximum value of accumulable dry matter), while *b* and *k* are the parameters that fit the experimental data. In particular, the point of inflexion of the curve occurs in the day which corresponds to the value b/k. With the aim of verifying the possible differences between the theses regarding dry matter accumulation, the analysis of variance was carried out on parameters *a*, *b* and *k* of the growth curves. As these parameters are certainly interdependent for determining the course of curves, a multivariate analysis using Wilks' statistics (Rao, 1973) was made, in addition to the univariate analysis. The graphs of the growth curve of dry matter over time were made only for the treatments which resulted significant to the analysis of variance. Furthermore, the absolute Crop Growth Rate (CGR), was obtained from valued biomass parameters, using the formula (Causton and Venus, 1981):

$$CGR(g * m^{-2} * d^{-1}) = \frac{dw}{dt} = ak * \exp^{(b-kt)} * \exp(-\exp^{(b-kt)})$$

Results and discussion

The Gompertz curve adapted well to the experimental data relative to every species, harvest time, cutting height and replication, with high R^2 (more than 80%) and the three parameters were always highly significant.

The results of the analysis of variance, both univariate and multivariate, relative to the parameters of curves are reported in Table 1.

Even though it is not supported by a statistical test, given the exiguity of the freedom degrees of error, the species differed markedly. In fact, the sainfoin not only provided higher values of dry matter, but it also did so more quickly (Fig. 1a). The two species showed even more accentuated differences in CGR curves (Fig. 1b), which shows how the sainfoin already reached the absolute maximum growth rate around the 30th day from the vegetative resumption, with values of about 7 g m^2 d^1 . The cocksfoot, instead, showed the maximum CGR value inferior to 3 g m^2 d^1 and it reached this level 65 days after the vegetative resumption. The sainfoin, however, exhausted its capacity to accumulate new dry matter in about 90 days, while the cocksfoot was more constant, having a growth period almost twice as long.

Among the harvest times, that done at 15 cm of height was the most productive, both for total accumulation of dry matter (Fig. 2a) and in the absolute growth rate (Fig. 2b), while the harvest at 10 cm turned out to be the worst. In addition to the significance of the multivariate test, these results are confirmed, above all, by the significance of *a* parameter (related to the final accumulation of dry matter), to a lesser degree by that of *k* parameter (influential on the course of the curve), while *b* parameter (also influential on the course of the curve) was never significant. The linear and quadratic components of the harvest time were both significant.

Table 1. Results of univariate and multivariate analysis of variance of curves parameters

Sources of variation	d.f.	a	b	k	Lambda of Wilks
Replication	2				
Crops (C)	1	-	-	-	-
Error	2				
Harvest time (Ht)	2	***	n.s.	*	**
Ht Linear (Li)	(1)	**	n.s.	**	**
Ht Quadratic (Qu)	(1)	***	n.s.	n.s.	**
Ht x C	2	***	n.s.	*	**
Li x C	(1)	n.s.	n.s.	*	n.s.
Qu x C	(1)	***	n.s.	n.s.	**
Error (b)	8				
Cutting height (Ch)	1	***	n.s.	***	***
Ch x C	1	n.s.	n.s.	*	n.s.
Ch x Ht	2	n.s.	n.s.	n.s.	n.s.
Li x Ch	(1)	n.s.	n.s.	n.s.	n.s.
Qu x Ch	(1)	n.s.	n.s.	n.s.	n.s.
Ch x Ht x C	2	n.s.	n.s.	n.s.	n.s.
Li x Ch x C	(1)	n.s.	n.s.	n.s.	n.s.
Qu x Ch x C	(1)	n.s.	n.s.	n.s.	n.s.
Error (c)	12				
Total	35				

Within the species, however, the trend of curves above mentioned appeared to be valid and very evident only for the sainfoin (Fig. 3, in which vertical lines point out the days of cuttings), since for cocksfoot the differences among the treatments were less marked and the yields tended to increase passing from the harvest time of 10 to that of 20 cm (Fig. 4, in which vertical lines point out the days of cuttings). In the "harvest time x species" interaction, only the significance of the linear component was lost.

As for the cutting heights, the one done close to the ground obtained about 0.5 t ha^{1} of dry matter more than the one at 5 cm (Fig. 5a). The CGR of the two cuttings, moreover, presented the same maximum value (less than 5 g m^{3} d^{1}), even if, between the two ways of cutting, that at 5 cm of height achieved it 5 days earlier (Fig. 5b).

Conclusions

The functional analysis with the Gompertz curve has shown to be suitable for the adaptation of the experimental data relative to the production of dry matter after each harvesting. The following analysis of variance, univariate and multivariate, of the parameters relative to the curves has allowed a clear discrimination of the growth trends of the treatments examined. The cocksfoot showed to be less competitive than sainfoin, both for its lower dry matter production and for the greater number of cuttings required. The harvest time at 15 cm was, on the whole, the best, while between cutting heights, that done at ground level appeared, as was expected, more productive than the harvest carried out at 5 cm height.

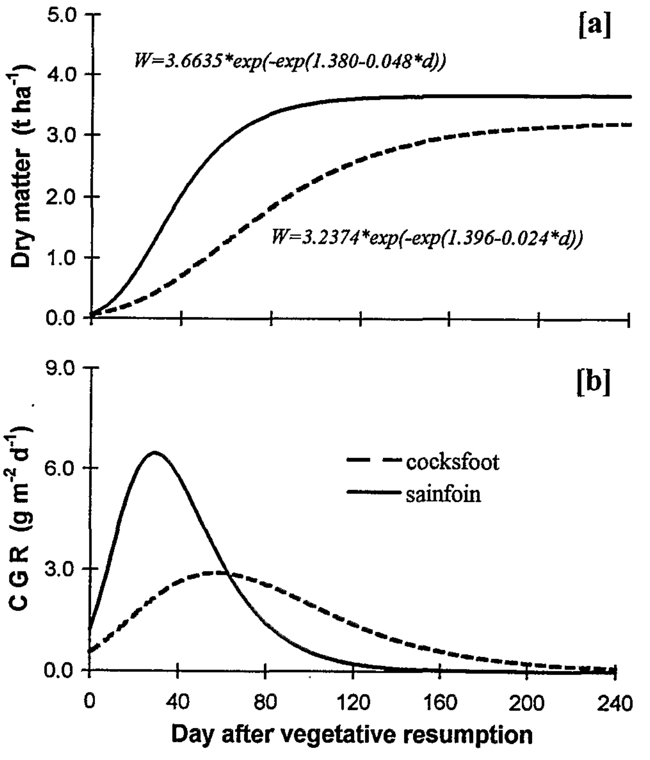

Fig. 1. Mean trend of accumulated production of dry matter and of crop growth rate (CGR) in sainfoin and cocksfoot.

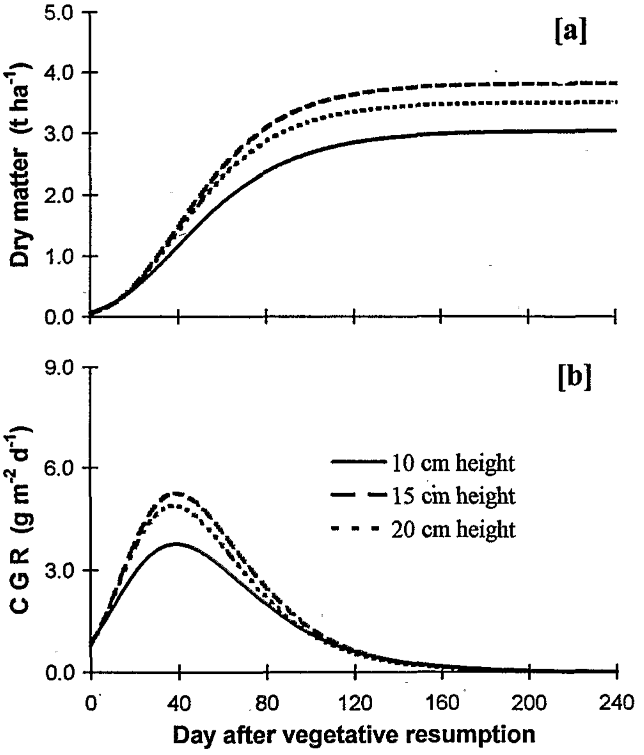

Fig. 2. Mean trend of accumulated production of dry matter and of crop growth rate (CGR) in relation to the 3 harvest times.

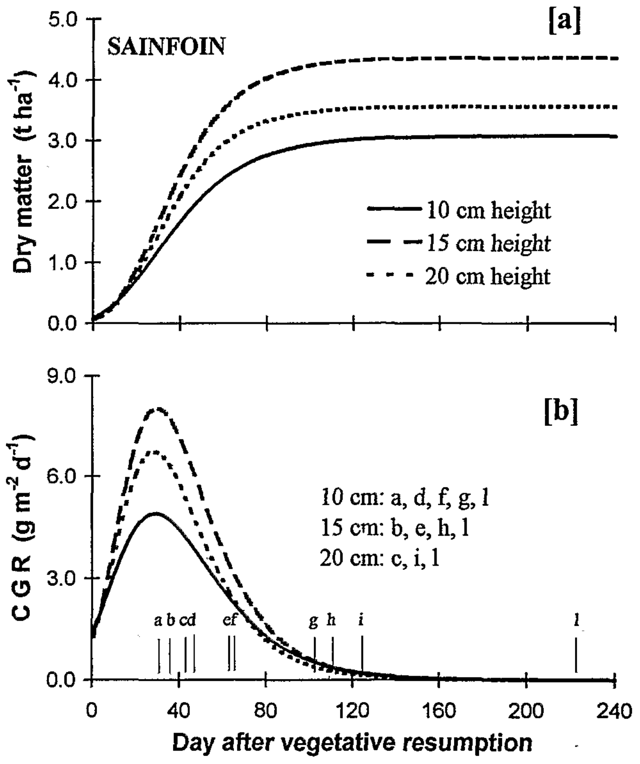

Fig. 3. Mean trend of accumulated production of dry matter and of crop growth rate (CGR) in sainfoin, in relation to the 3 harvest times.

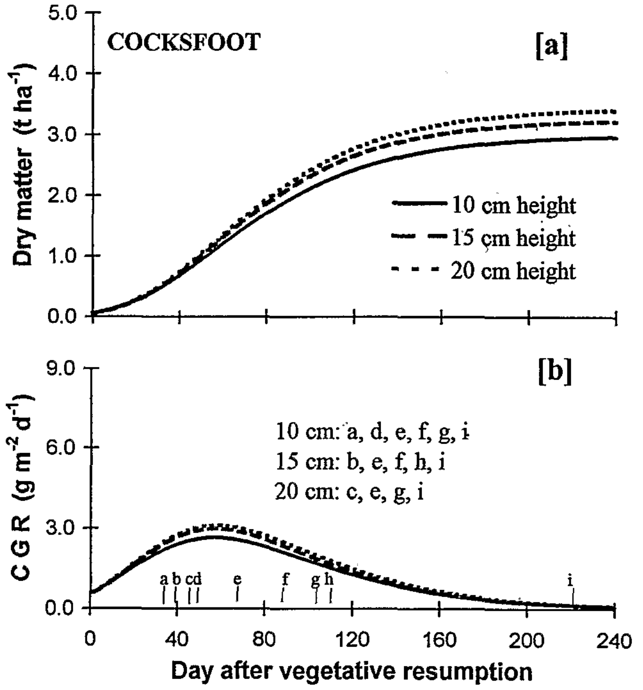

Fig. 4. Mean trend of accumulated production of dry matter and of crop growth rate (CGR) in cocksfoot, in relation to the 3 harvest times.

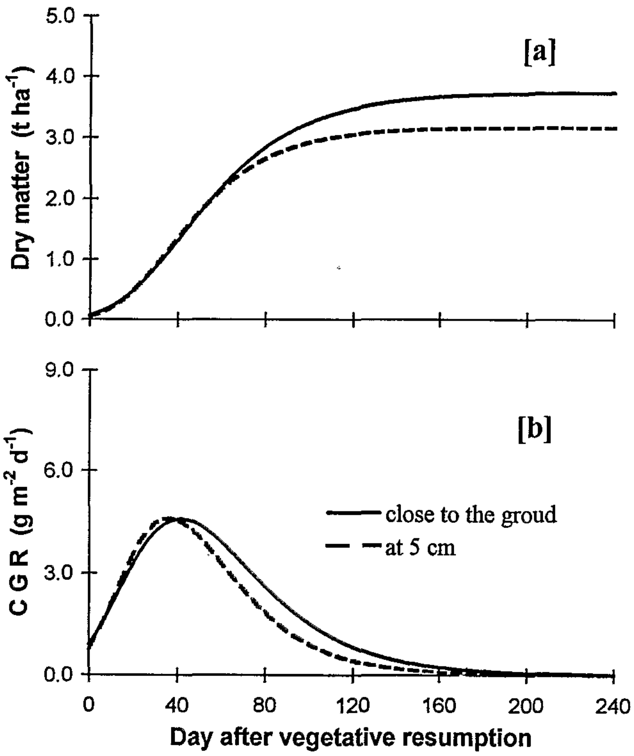

Fig. 5. Mean trend of accumulated production of dry matter and of crop growth rate (CGR) in relation to the 2 cutting heights.

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