RADIATION BALANCE AND PRODUCTION OF FORAGE CROPS IN A MEDITERRANEAN REGION

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ABSTRACT

This study is devoted to measure the radiation use efficiency (*RUE*) and the extinction light coefficient (k) of a sainfoin crop, cultivated in a site of Southern Italy. The same parameters are measured also for the global solar radiation (in this case *kg* and *RUEg*, respectively). The crop was maintened in well watered conditions and the measures were carried out during four cut cycles, one during 1994 and three during 1995. Transmitted, incident, soil and canopy reflected radiations were measured continously during the growth season. The results were given a mean of 2.61 and 1.2 g MJ^{-1} for *RUE* and *RUEg*, respectively and 0.86 and 0.71 for k and *kg*, respectively. These values, comparable with other similar results, confirm the good adaption of this forage crop to the Mediterranean conditions.

INTRODUCTION

This work concerns the light interception and the solar radiation use of sainfoin, a forage crop that could well adapt in the Mediterranean area, being hardy and drought resistant.

One of the needs for determining the degree of adaptability of a crop in a given environment is the efficiency of the solar radiation use (Radiation Use Efficiency, *RUE*) in the growth and crop production (i.a. Varlet-Grancher *et al.*, 1982; Russel, 1993). This is very important, particularly, for the forage crops, due to their low economical value. Furthermore, in the modern agricultural research one of the most useful methods to analyse the crop productivity along the growth season is the simulation by means of a crop production model (for example CERES, CROPSYST): one of the fundamental parameters to input in the model is the light interception coefficient, k, a physical parameter which gives information about the capability of a canopy to intercept visible radiation, i.e. the energy necessary for photosynthesis (a synthesis is, among others, in Bonhomme, 1993).

The analysis of radiation balance and interception could be particularly important for a forage crop, where the canopy is cut down in a systematic way, so that the *RUE* and k may change during the growth period with the environment conditions.

MATERIALS AND METHODS

We study the efficiency of radiation use and interception coefficient both for Photosynthetically Active Radiation (PAR, $350<\lambda<700$ nm) and global solar radiation ($300<\lambda<3000$nm).

For PAR the relevant definitions are: (i.a. Gallo *et al.*, 1993)

$$RUE = \frac{CDM}{PARa} \quad (1)$$

where *CDM* is accumulated dry matter (in g m^{-2}) and *PARa* is PAR absorbed (in MJ m^{-2}). PAR absorbed is almost equivalent to PAR intercepted by the crop (Chartier *et al.*, 1993) given by the relationship

$$PARi = PAR0 + PARrs - PARr - PARt \quad (3)$$

where *PARrs* and *PARr* is PAR reflected by the soil and by the canopy, respectively.

PARt is PAR transmitted to the soil and can be directly measured or evaluated with the model (Monsi and Saeki, 1953):

$$PARt = PAR0 e^{-kLAI} \quad (2)$$

where *PAR0* is PAR incident on the and *LAI* (m^2 m^{-2}) is leaf area index, k is the interception (or extinction) coefficient.

For global solar radiation the definitions are the same, with *PAR* substitued by global radiation R and the same subscripts.

The trial was carried out at Rutigliano (Southern Italy), lat. 41°N, long. 15° E, 122 m a.s.l.); the soil was clay (41%) and quite shallow (0.7 m).

The sainfoin (*Onobrychis vicaefolia* Scop., cv. Vala) was sown at November, 16th 1994. Measurements were done between June 1st (first cut) and July 18th 1995 (fourth cut), so that three complete growth cycles were studied (hereafter called I, II and III, respectively). The canopy was cut at 5 cm, when it reached about 22 cm of height. The synthesis of cut practices is given in table 1. Transmitted radiations were measured at two points (2 linear sensors), at soil level, in the middle of a plot of sainfoin (about 10 m^2); reflected radiation from canopy was measured, at 5 cm above the canopy, in a point in the center of the plot, while the radiation reflected from the soil was measured in a point near the experimental field.

Measurements of global radiation and PAR were made with self-made linear sensors, 1 m long, containing 10 silicium cells, sensible to solar radiation and only visible radiation, respectively. Incident solar radiation was measured by an Eppley solarimeter and incident PAR was measured by a Quantum sensor (LI-COR, mod. LI-190SA). All the parameters were measured continuously (every 10 s) and stored as 15 min-avarage by a CR10 data logger (Campbell Scientific, Logan, USA).

LAI (determined with an electronic area meter, LI-COR 3000 A) was weekly measured on 12-15 samples of plants consecutively harvested from a 1-m row. Daily LAI was linearly interpolated between two sampling dates. The same plant samples were utilized for determining the above-ground crop dry weight, after oven-drying for 48 h at 80 °C. For each cycle *CDM* was plotted versus accumulated *PARi* and accumulated *Ri*. Linear regressions forced through origin, were fitted to each data set, because intercepts were not significantly different from zero. The slope of these regressions is an accurate estimate of *RUE* and *RUEg,* respectively.

During 1994 the same experiment was carried out for just one cut cycle, between May 19th and June 7th; in this case the crop was sown on November, 1993.

RESULTS AND DISCUSSION

In Table 2 the radiation use efficiency for global and visible radiation are shown for the three experimental cycles during 1995. Both *RUE* and *RUEg* increased, even if ligthly, with the cycle, i.e. the efficiency of the radiation improved as long as the day of the year. This is probably due to the increasing of the air temperature and the solar radiation, consequently to the prolongation of the day. On the other hand, the increasing of the forage production, in well watered conditions, with the increasing of the day temperature and radiation is known for the Mediterranean area (Rizzo and De Giorgio, 1982). During 1994 *RUE* was 2.45 g MJ^{-1} and *RUEg* was 1.14 g MJ^{-1}. During the summer, for forage crops under dry conditions, the water stress could determine a decreasing of green production. During our experiment, in order to prevent the water stress risk, three supplementary irrigations were given to the canopy; in this manner the productions were stabilized and the radiation use efficiency was the only function of the growth season.

In the same table (2) the extinction coefficients, both for PAR and global radiation, are given. In both cases the extinction coefficient is almost constant: this is consistent with the fact that the interception of the radiation by the canopy is only a function of the architectural structure and of optical leaf characteristics (Varlet-Grancher *et al.*, 1989; Sinoquet and Andrieu, 1993). During 1994 *k* was 0.88 and *kg* was 0.72.

CONCLUSIONS

The mean value of the four cycles (one in 1994 plus three in 1995) is 2.61 for *RUE* and 1.2 for *RUEg*. These values are comparable with other forage crops in the Mediterranean region, so that it can be affirmed that sainfoin could be well adapted to this area.

For the extinction coefficients, the mean values in the four considered cycles were 0.86 and 0.71 for *k* and *kg*, respectively. This values are not so far from the other extinction coefficients in the literature (0.88 for Medicago sativa by Gosse *et al.*, 1982; 0.97 for Medicago sativa by Fuess and Tesar, 1968; 0.83 for Lupinus by Varlet-Grancher *et al.*, 1989).

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Table 1
Synthesis of cut practices.

Cycle	Date of cut	Number of days between cuts	Maximum height (cm)
I	May 19th	18	22 ± 1
II	June 13th	24	21 ± 1
III	July 17th	23	23 ± 1

Table 2
Radiation Use Efficiency and extinction coefficient.

Cycle	RUE ($g\ MJ^{-1}$)	RUEg ($g\ MJ^{-1}$)	*k*	*kg*
I	2.25	1.10	0.87 ± 0.02	0.70 ± 0.01
II	2.70	1.21	0.86 ± 0.02	0.69 ± 0.01
III	3.05	1.35	0.84 ± 0.02	0.72 ± 0.01