NARDI FUNDULEA, ROMANIA ROMANIAN AGRICULTURAL RESEARCH, NO. 33, 2016
www.incda-fundulea.ro Print ISSN 1222-4227; Online ISSN 2067-5720

RESEARCHES REGARDING THE SOLAR RADIATION BIOCONVERSION IN *DACTYLIS GLOMERATA* L. PURE STANDS AND IN MIXTURE WITH *MEDICAGO SATIVA* L.

Ana-Maria Stanciu[1], Niculae Dincă[1], Daniel Dunea[2]

[1]University of Agronomical Sciences and Veterinary Medicine Bucharest, Faculty of Agriculture, 59 Mărăşti Blv., Sector 1, Bucharest, Romania. E-mail: anaglavan83@yahoo.com, nicudinca@yahoo.com

[2]Valahia University of Targoviste, Faculty of Environmental Engineering and Food Science, Aleea Sinaia no.13, Targoviste, Romania. E-mail: dunea@valahia.ro

ABSTRACT

The present study aimed to estimate the solar radiation conversion into forage production (yield) for orchardgrass (*Dactylis glomerata* L.) species in the specific conditions of the Romanian Plain. A field experiment with 2 varieties of orchardgrass (Ambassador and Regent) in pure stand and in mixture with 30% alfalfa (*Medicago sativa* L.) was conducted at Moara Domneasca Didactic Farm of University of Agronomical Sciences and Veterinary Medicine Bucharest. The experiment was arranged in a split-plot completely randomized block design, with four replicates in a bi-factorial arrangement with ten experimental variants and three cutting cycles. The weather parameters were collected by an automatic meteorological station installed in the location of Moara Domneasca. During the experiments the coefficient of solar energy conversion into yield increased with the canopy growth to earing stage, in the first cutting cycle, and decreased at the following cycles with the plants growth and development. During three years of experiments (2009-2011), the Regent cultivar presented on average, the highest values of Radiation Use Efficiency, respectively 1.82 g DM/MJ, in the first harvest cycle, in the mixture variants with alfalfa. The studied variables for yield formation were influenced by the growth stage, crop arrangement, cutting cycle and leaf area index.

Key words: photosynthetically active radiation, dry matter, radiation use efficiency, grass-legume interactions.

INTRODUCTION

Solar radiation represents an electro-magnetic energy flow that must be instantly intercepted and used by plants as it cannot be stored for a later use (Tsubo et al., 2001). The importance of radiation appears from its vital role played in the photosynthesis process (Khan et al., 2010). Photosynthesis involves a process by which green plants use sunlight, water and nutrients to synthesize organic material from inorganic substances (Biscoe and Gallagher, 1978).

However, not all incident or global fluxes of radiation are intercepted by plants. The fraction of solar radiation used by the plants is known as PAR - Photosynthetically Active Radiation (Vargas et al., 2002). In most cases, PAR is approximated 0.5 of the global radiation (Bonhomme, 2000).

Solar radiation plays a crucial role in achieving crop yield. Thus, if the canopy captures a higher amount of PAR, a higher amount of dry matter will result.

A series of factors related to the genetic characteristics of each species and cropping technology factors influences the biological efficiency of solar energy conversion into dry matter (Dunea and Motcă, 2006).

In the absence of biotic and abiotic stresses, dry matter accumulation in plants depends on the solar radiation absorbed by the canopy.

The relationship between dry matter production and intercepted solar radiation was called radiation use efficiency (RUE) being expressed in g Dry Matter/MJ (Monteith, 1972, 1977).

Watson (1958) pointed out that the crop growth is a product between the real rate of assimilation on leaf and the total leaf area.

Instead of being an important point for analysis, the leaf area index (LAI) is actually an intermediate variable in determining the radiation absorbed and its distribution within the canopy.

Photosynthetically active radiation concept was originally developed for annual

Received 18 June 2015; accepted 7 December 2015; First Online: March, 2016. DII 2067-5720 RAR 2016-93

crops. Generally, it presented the interception of solar radiation by aboveground biomass, assuming that the production of roots has a smaller and constant proportion of the total biomass (Sinclair and Muchow, 1999).

Later on, PAR concept was used to predict the production of biomass in perennial species such as alfalfa (Robertson et al., 2002), perennial ryegrass and white clover (Lantinga et al., 1999) or red clover (Dunea and Motcă, 2006). It was demonstrated that PAR is directly related to the ambient temperature (Sinclair and Muchow, 1999; Dunea, 2008). For example, Justes et al. (2002) found an increasing of PAR in alfalfa from 0.37 to 1.02 g DM/MJ when temperatures increased from 6.4ºC to 11.4 ºC in spring.

A series of experiments were made regarding the effect of shadowing, considered as a reducing factor of PAR absorption, on the forage yield and quality (Moga et al., 1996).

Consequently, the forage species yield having C3 photosynthesis type does not depend as much on shading, but on the radiation use efficiency (Belesky et al, 2006; Peri et al., 2002).

Keating and Carberry (1993) found that the productivity per unit of incident radiation can be improved by adopting a cropping system that ensures a higher rate of radiation interception. Mixed cropping systems, including grass-forage mixtures, are one of the main ways to improve the interception of solar radiation in canopies during the growth season (Jahansooz et al., 2007; Dunea and Dinca, 2014).

In this context, the paper presents the potential of solar energy conversion into net yield in orchardgrass (*Dactylis glomerata* L.) depending on genotype, cropping arrangement and fertilization systems in the climatic conditions of Romanian Plain.

MATERIAL AND METHODS

Experiments were performed at Moara Domneasca Experimental Farm, Romania, between 2009 and 2011.

The soil type in experimental field was a red pre-luvisol with the following characteristics: loam-clay texture, average humus content in the A horizon (2.77%) and relatively high in A/B (~ 1.2%), weak acid-neutral reaction in A horizon (pH of 6.29 to 6.64); 17 ppm phosphorus content (weak-average content); 184 ppm potassium content (optimal content). The soil is also representative for the Romanian Plain.

Multi-annual average rainfalls of 556.1 mm and an annual average temperature of 10.5ºC characterize the climate of the area. During the growing season (March-September), there are 380 mm of rainfall on average. Compared with the normal climatic regime of the area in which the experimental field was located, the years of experimental trials (2009-2011) were characterized by a deficit of precipitations during the growing season and annual temperatures higher than the multiannual average.

In the experiment, we studied two varieties of orchardgrass (Regent and Ambasador) in pure stand and in mixture with 30% alfalfa.

Other species of perennial grasses (*Festuca pratensis*, *Festuca arundinacea* and *Bromus inermis*) were tested for comparative analysis with *Dactylis glomerata* regarding the biological characteristics in the same cropping arrangements.

Each year, fertilizers containing nitrogen and phosphorus were applied at a dosage of 100 kg N/ha and 50 kg P_2O_5/ha.

Experimental Factors

Factor A: cropping arrangement;

a_1 = grasses in pure stands;

a_2= grass species 70% + *Medicago sativa* 30% - *La Bella Campagnola* cultivar;

Factor B: Species and cultivars of perennial grasses;

b_1= *Dactylis glomerata* – Regent;

b_2= *Dactylis glomerata* – Ambasador;

b_3= *Festuca pratensis* – Transilvan;

b_4= *Festuca arundinacea* – Adela;

b_5= *Bromus inermis* – Olga.

Several elements were determined dynamically in the growth season as follows:

RUE = Radiation use efficiency, represents biological efficiency of the intercepted radiation or conversion of the radiation energy into biomass (g DM/MJ):

$$RUE = Y / \sum R_a$$

where:
Y = Yield (g DM/m^2);
R_a = Daily intercepted radiation by the leaves (MJ/m^2/day).

$$R_a = \varepsilon_i \cdot R_i$$

where:
ε_i = Coefficient of daily PAR interception;
R_i = PAR (in the visible spectrum: 0.4-0.7 µm) (MJ/m^2/day).

$$\varepsilon_i = \beta(1 - e^{-k \cdot LAI})$$

where:
β = Coefficient of absorption for the canopy considered to have a general value around 0.95 (Varlet-Grancher et al., 1989);
k = Coefficient of radiation extinction with a general value of 0.60 for grasses;
LAI = leaf area index (m^2/m^2).

$$LAI = \frac{D * S}{10000}$$

where:
D = plant density (no. of sprouts/m^2);
S = leaf area (cm^2)
$S = L \cdot l \cdot k \cdot$ *no. of leaves/sprout*
where:
L = leaf length (cm);
l = leaf width (cm);
k = correction factor for grasses (0.905)

$$R_i = 0.48 \cdot R_g$$

where:
0.48 – quantum of intercepted PAR;
R_g = incident global radiation (MJ/m^2/day).

Along with determining the RUE values, the energy efficiency or conversion coefficient of solar energy into chemical energy (C_e) was also determined:

$$C_e = EB / \sum R_a \cdot 100$$

where:
EB = Equivalent of the conversion efficiency in gross energy ~0.017 MJ/g DM (Andrieu et al., 1988).
R_a = Daily intercepted radiation by the leaves (MJ/m^2/day)

Each year, in the first cutting cycle, measurements were made from apex phase - 10 cm (15 to 23 April) to early flowering (May 8 to 13). The determinations for the other crop cycles were performed every 20 days until cutting.

RESULTS AND DISCUSSION

Radiation Use Efficiency (RUE)

During the period of experiments (2009-2011), RUE that led to net yield increased on average with canopy growth only at first cutting cycle in both tested cultivars of orchardgrass; RUE decreased with crop growth at the following two cutting cycles.

In mixture variants, the solar energy conversion efficiency was usually lower than in pure stands for all of crop cycles (Table 1).

Table 1. Radiation Use Efficiency (RUE) of orchardgrass (*Dactylis glomerata* L.) (average of 2009-2011 period)

Period	RUE (g DM/MJ)			
	Pure stand		Mixture with alfalfa	
	Regent	Ambasador	Regent	Ambasador
Cutting cycle I				
15-23.04	1.27	1.27	1.24	1.14
8-13.05	1.69	1.73	1.82	1.70
Cutting cycle II				
6-10.06	1.59	1.66	1.75	1.71
26-30.06	0.97	0.82	0.85	0.78
Cutting cycle III				
27-2.08	1.50	1.66	1.66	1.66
17-23.08	0.81	0.69	0.67	0.58

The maximum conversion efficiency was recorded in all variants during May 8 to 13, respectively from 1.69 to 1.82 g DM/MJ in Regent variants and 1.70 to 1.73 g DM/MJ in Ambasador cultivar.

The two tested varieties of orchardgrass showed a minimum conversion efficiency during the third cycle between 17 and 23 August namely from 0.67 to 0.81 g DM/MJ for Regent and from 0.58 to 0.69 g DM/MJ for Ambasador.

Sinoquet et al. (1990) identified values of 1.63 for tall fescue (*Festuca arundinacea* Schreb.) and 1.10 g DM/MJ for white clover. Other experiments found RUE values of 1.9 for perennial grasses and 1.72 g DM/MJ for legumes in pure stands (Gosse et al., 1986). In pure stand, white clover recorded a maximum RUE of 1.77 g DM/MJ, while hybrid ryegrass reached 1.82 g DM/MJ (Dunea et al., 2015).

Daily efficiency of PAR interception (ε_i)

PAR interception and absorption coefficients in *Dactylis glomerata* cultivars were directly influenced by the size of the leaf area per unit of ground area (LAI).

On average, for the three years of experimental trials, the daily PAR interception efficiency usually increased with the growth stages of orchardgrass plants and presented higher values in the mixture variants.

In the conditions of experimental variants, the real interception efficiency of solar radiation was reduced during drought periods (June and August) of the growing season.

In all cropping variants, the maximum coefficient of solar radiation interception was achieved at the beginning of earing phase (May 8 to 13) reaching values between 0.74 to 0.86 for Regent variety and between 0.80-0.88 for Ambasador variety (Table 2).

Table 2. Coefficient of PAR daily interception (εi) (average of 2009-2011 period)

Period	Coefficient of daily interception of PAR (εi)			
	Pure stand		Mixture with alfalfa	
	Regent	Ambasador	Regent	Ambasador
Cutting cycle I				
15-23.04	0.47	0.51	0.62	0.71
8-13.05	0.74	0.80	0.86	0.88
Cutting cycle II				
6-10.06	0.33	0.33	0.39	0.33
26-30.06	0.45	0.48	0.60	0.51
Cutting cycle III				
27-2.08	0.32	0.29	0.35	0.30
17-23.08	0.31	0.27	0.35	0.36

The minimum efficiency of PAR interception was achieved in the third cutting cycle for all experimental variants between August 17 and 23 recording values between 0.31 and 0.35 for Regent, respectively 0.27 to 0.36 for Ambasador.

Conversion of solar energy into chemical energy (C_e%)

The transformation of absorbed solar energy at canopy level into chemical energy stored in yield was done with the highest intensity in the first cutting cycle for all experimental variants.

Transformation of solar radiative energy absorbed by canopy into chemical energy stored in yield was performed with losses of up to 97-98%.

The amount of chemical energy produced was on average 2.52-2.60% for Regent variety and between 2.33 and 2.55% for Ambasador variety from the absorbed radiative energy by the canopies in the first cutting cycle (Table 3).

Table 3. Conversion efficiency of solar energy into chemical energy (C_e) (%) (average of 2009-2011period)

Cutting cycle	Cropping arrangement			
	Pure stand		Mixture with alfalfa	
	Regent	Ambasador	Regent	Ambasador
I	2.52	2.55	2.60	2.33
II	2.18	2.10	2.30	2.36
III	1.96	2.00	1.98	1.90

The smallest amount of chemical energy was recorded in the third cutting cycle, i.e. from 1.96 to 1.98% for Regent, and 1.90-2.00% for Ambasador variety.

Generally, from 0.25% to 0.5% of the light from the sun is converted into chemical energy in most of the plants and is stored in yield (corn seeds, potato starch, etc.). The sugarcane had solar energy storage efficiency up to 8% (Monteith, 2011).

Correlations between yield factors and net forage yield in orchardgrass

The most significant correlations with yield were identified for leaf area index and radiation absorbed by the plants (R_a).

During the period of experimental trials, both varieties of orchardgrass showed positive correlations between leaf area index and average forage yield. Dry matter accumulation was 94% correlated with the leaf area index in Regent cultivar of orchardgrass and 98% in Ambasador (Figures 1 and 2).

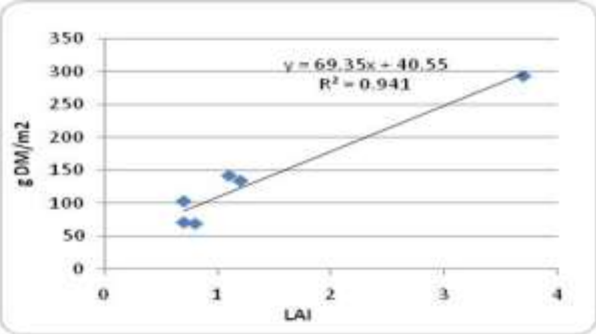

Figure 1. Correlation between LAI and forage yield in *Dactylis glomerata*, Regent cultivar

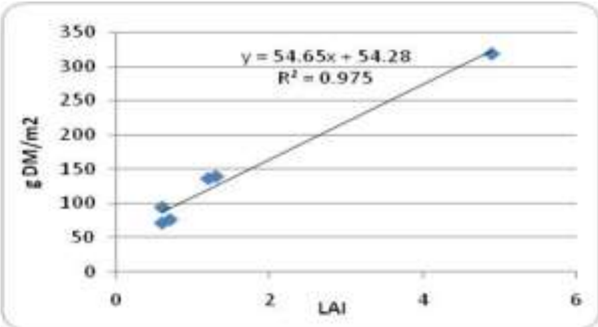

Figure 2. Correlation between LAI and forage yield in *Dactylis glomerata*, Ambasador cultivar

Furthermore, positive correlations have been observed between the intercepted or absorbed radiations by canopy (R_a) and yield; the coefficients of correlation were 0.992 for Regent variety and 0.966 for Ambassador variety (Figures 3 and 4).

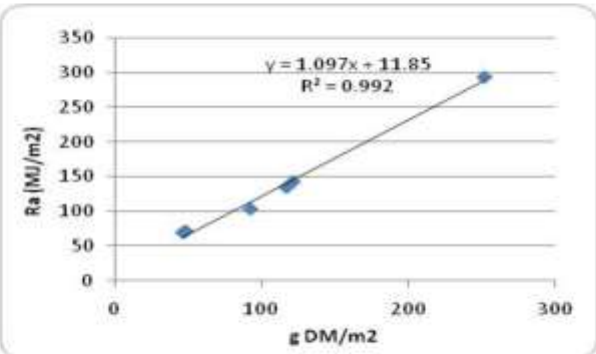

Figure 3. Correlation between absorbed radiation (R_a) and forage yield in *Dactylis glomerata*, Regent cultivar

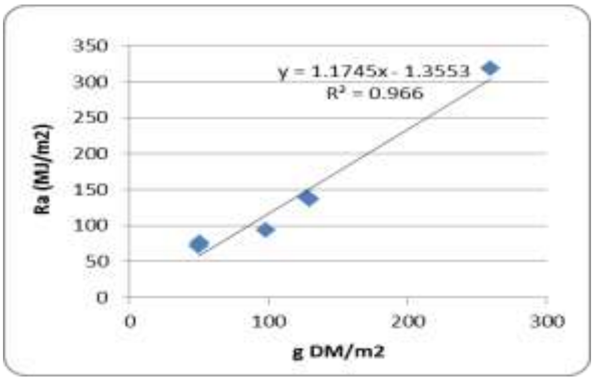

Figure 4. Correlation between absorbed radiation (R_a) and forage yield in *Dactylis glomerata*, Ambasador cultivar

Comparison of orchardgrass yield with other perennial grasses yields (2009-2011)

Based on the experimental results obtained between 2009 and 2011, it was estimated that the average of dry matter accumulation was higher in the variants with grass-alfalfa mixtures (Figure 5).

Dry matter yield accumulated by *Dactylis glomerata* species recorded more than 6 t DM/ha in all cropping variants, i.e., between 6.22 and 6.49 t/ha in pure stands and between 6.70 and 6.97 t/ha in mixtures with *Medicago sativa*.

Compared with other perennial grasses tested in the same experience, *Dactylis glomerata* species was exceeded in terms of yield potential only by smooth bromegrass (*Bromus inermis*) that recorded average yields of 6.88 t DM/ha in pure stand and 7.81 t DM/ha in grass-legume mixture.

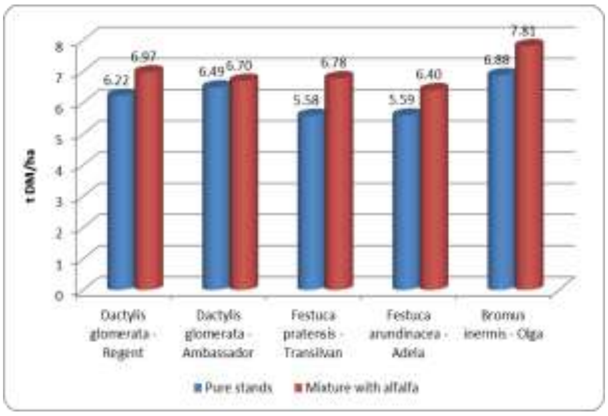

Figure 5. Dry matter production (t DM/ha) of tested variants: pure stands; mixtures with alfalfa (average of 2009-2011 period)

The effect of grass species on dry matter yield

Analyzing the effect of perennial grass species on dry matter yield, it was observed that during the experimental period (2009-2011), the overall average yield of variants of 6.54 t DM/ha is a good value for the Romanian Plain climatic conditions (Table 4).

Compared to the overall average (6.54 t DM/ ha), smooth bromegrass has recorded a 12% increase of yield, with a very significant difference of 0.81 t DM/ha.

In experimental variants with *Dactylis glomerata* species were obtained a positive difference (0.06 t DM/ha) from the overall yield of grass species, without statistical significance.

Table 4. Effect of grass species on dry matter yield (average for 2009-2011 period)

Grass species	Yield		Difference		Statistical significance
	t/ha	%	t/ha	%	
Dactylis glomerata - Regent	6.60	101	0.06	1	
Dactylis glomerata - Ambasador	6.60	101	0.06	1	
Festuca pratensis - Transilvan	6.18	94	-0.36	-6	000
Festuca arundinacea - Adela	6.00	92	-0.56	-8	000
Bromus inermis - Olga	7.35	112	0.81	12	***
Overall average	6.54	100	Mt.		

LSD 5% = 0.16 t/ha; LSD 1% = 0.22 t/ha; LSD 0.1% = 0.30 t/ha.

Species of *Festuca arundinacea* and *Festuca pratensis* showed negative differences (0.36 t/ha, respectively 0.56 t DM/ha) from the overall average, differences that were significant for $p<0.001$.

Compared to the overall average (6.54 t DM/ha), the association of alfalfa with perennial grasses in mixtures provided an increase of 0.39 t DM/ha, which was distinct statistically significant ($p<0.01$).

The influence of cropping arrangement on dry matter yield

Based on the results shown in Table 5, it was observed that during the period of experiments, the dry matter yields were higher than in pure stands when perennial grass species were mixed with *Medicago sativa* (30% participation).

Table 5. Effect of cropping arrangement on dry matter yield (average for 2009-2011 period)

Variants	Yield		Difference		Statistical significance
	t/ha	%	t/ha	%	
Pure stand	6.15	94	- 0.39	- 6	00
Mixture	6.93	106	0.39	6	* *
Overall average	6.54	100	Mt		

LSD 5% = 0.20 t/ha; LSD 1% = 0.36 t/ha; LSD 0.1% = 0.80 t/ha.

Predicting dry matter yields for *Dactylis glomerata* species

In the climatic conditions of Central Romanian Plain that were specific to the 2009-2011 experimental period, the rate of assimilation of intercepted solar radiation by foliage (RUE) is the most significant variable to be considered for predicting the formation of yield**.**

The equation to predict yield for orchardgrass using multiannual experimental results is based on available PAR energy (R_a) as follows:

$$Y = RUE \cdot \sum R_a /100,$$

where:

RUE_1 = 1.5 g/MJ for cycle I;

RUE_2 = 1.2 g/MJ for cycle II;

RUE_3 = 1.0 g/MJ for cycle III.

Consequently, the variable element is R_a in the relation for estimating the forage yield, and depends on the species, variety, weather conditions during the growing season, and applied technology.

CONCLUSIONS

Mixtures of orchard grass with alfalfa provided a better solar radiation interception by the heterogeneous canopy during growth season.

The interception or absorption coefficients of the photosynthetically active radiation were influenced by a multitude of factors such as the variety of *Dactylis glomerata*, phenophase, cropping arrangement, cutting cycle and leaf area index (LAI).

On three-year average, radiation use efficiency increased with plant growth to earing phase in the first cutting cycle. RUE decreased in the following cycles with the canopy growth.

Given the experimental conditions, the real efficiency of solar radiation interception (εi) increased with the growth and development of orchard grass plants and decreased during drought periods (June and August).

In studied varieties of orchard grass, the transformation efficiency of absorbed solar energy in chemical energy stored in forage yield was 2-3%.

On average during the experimental period, dry matter yield was correlated positively with leaf area index and absorbed radiation by canopy in both varieties of orchard grass.

Based on the results, we can affirm that by using varieties of *Dactylis glomerata* and *Bromus inermis* with the same vegetation period of vegetation with *Medicago sativa* varieties, it is possible to obtain the highest dry matter yield comparatively with association in mixture between *Medicago sativa* and varieties of *Festuca pratensis* or *Festuca arundinacea.*

REFERENCES

Andrieu, J., Demarquilly, C., Sauvant, D., 1988. *Tables de la valeur nutritive des aliments*. In: Alimentation des bovins ovins & caprins, Editure Jarrige R., INRA, Paris.

Belesky, D.P., Chatterton, N.J., Neel, J.P.S., 2006. *Dactylis glomerata growing along a light gradient in the central Appalachian region of the eastern USA*. III. *Nonstructural carbohydrates and nutritive value*. Agrofor. Syst., 67.

Biscoe, P.V., Gallagher, J.N., 1978. *Physiological analysis of cereal yield. I. Production of dry matter*. Agric. Progress, 53: 34-50.

Bonhomme, R., 2000. *Beware of comparing RUE values calculated from PAR vs solar radiation or absorbed vs intercepted radiation*. Field Crops Researches, 68.

Dunea, D., Frăsin, L.B.N., Dincă, N., 2015. *Ecophysiological Responses of White Clover-Hybrid Ryegrass Mixture to Foliar Fertilisation*. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 43 (1): 173-178.

Dunea, D., Dincă N., 2014. *Improving land utilization using intensive grass-clover mixtures in forage production systems.* Romanian Agricultural Research, 31: 147-158

Dunea, D., 2008. *Temperature effect on growth and development indices in uniform and heterogeneous red clover canopie*s. Lucrări ştiinţifice Zootehnie şi Biotehnologii, 41: 303-311.

Dunea, D., Motcă, Gh., 2006. *Solar radiation bioconversion by red clover (Trifolium pratense L.) cultivars*. Analele Universității Valahia, Târgoviște - Agricultură: 25-31.

Gosse, G., Varlet-Grancher, C., Bonhomme, R., Chartier, M., Allirand, J.M., Lemaire, G., 1986. *Production maximale de matière sèche et rayonnement solaire intercepté par un couvert vegetal*. Agronomie, 6: 47-56.

Jahansooz, M.R., Yunusa, I.A.M., Coventry, D.R., Palmer, A.R., Eamus, D., 2007. *Radiation and water use associated with growth and yields of wheat and chickpea in sole and mixed crops*. European Journal of Agronomy, 26.

Justes, E., Thiebeau, P., Avice, J.C., Lemaire, G., Volenec, J.J., Ourry, A., 2002. *Influence of summer sowing dates, N fertilization and irrigation on autumn VSP accumulation and dynamics of spring regrowth in alfalfa (Medicago sativa L.)*. Journal of Experimental Botany, 53.

Keating, B.A., Carberry PS., 1993. *Resource capture and use in intercropping: solar radiation*. Field Crops Research, 34.

Khan, H.R., Paull, J.G., Siddique, K.H.M., Stoddard, F.L., 2010. *Faba bean breeding for drought-affected environments: A physiological and agronomic perspective*. Field Crops Research, 115: 279-286.

Lantinga, E.A., Nassiri, M., Kropff, M.J., 1999. *Modelling and measuring vertical light absorption within grass-clover mixtures*. Agricultural and Forest Meteorology, 96: 71-83.

Moga, I., Schitea, M., Mateiaş, M., 1996. *Plante furajere*. Ed. Ceres, București.

Monteith, J.L., 1972 . *Solar radiation and productivity in tropical ecosystem* in Stockle, O.C., Kemanian, R.A., 2009, *Crop Physiology – Applications for genetic improvement and agronomy*. Ed. Academic Press.

Monteith, J.L., 1977. *Climate and the efficiency of crop production in Britain* in Stockle, O.C., Kemanian, R.A., 2009. *Crop Physiology – Applications for genetic improvement and agronomy*, Ed. Academic Press.

Monteith, J.L., 2011. *Review of radiation interception and radiation use efficiency in intercropping in relation to the analysis of wheat/faba bean intercropping system.* In: Yahuza, I., Journal of Biodiversity and Environmental Sciences, 1 (5).

Peri, P.L., McNeil, D.L., Moot, D.J., Varella, A.C., Lucas, R.J., 2002. *Net photosynthetic rate of cocksfoot leaves under continuous and fluctuating shade conditions in the field*. Grass Forage Sci., 57.

Robertson, M.J., Carberry, P.S., Huth, N.I., Turpin, J.E., Probert, M.E., Poultron, P.L., Bell, M.J., Wright, G.C., Yeates, S.J., Brinsmead, R.B., 2002. *Simulation of growth and development of diverse legumes species in APSIM*. Australian Journal of Agricultural Research, 53 (4): 429-446.

Sinclair, T.R., Muchow, R.C., 1999. *Radiation use efficiency*. Advances in Agronomy, 65.

Sinoquet, H., Bruno, M., Gastal, F., Bonhomme, R., Varlet-Grancher C., 1990. *Modelling the radiative balance of the component of a well mixed canopy: application to a white clover-tall fescue mixture*. Acta Ecologica, 11: 469-486.

Tsubo, M., Walker, S., Mukhala, E., 2001. *Comparisons of radiation use efficiency of mono-/intercropping systems with different row orientations*. Field Crops Research, 71 (1): 17-22.

Vargas, L.A., Andersen, M.N., Jensen, C.R., Jorgensen, U., 2002. *Estimation of leaf area index, light interception and biomass accumulation of Miscanthus sinensis 'Goliath' from radiation measurements*. Biomass and Bioenergy, 22**.**

Varlet-Grancher, C., Gosse, G., Chartier, M., Sinoquet, H., Bonhomme, R., Allirand, J.M., 1989. *Mise au point : rayonnement solaire absorbé ou intercepté par un couvert végétal*. Elsevier/INRA: 419-439.

Watson, D.J., 1958. *The dependence of net assimilation rate on leaf area index*. Annals of Botany, N.S., 22: 37-54.