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IMPROVING LAND UTILIZATION USING INTENSIVE GRASS-CLOVER MIXTURES IN FORAGE PRODUCTION SYSTEMS

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ABSTRACT

The paper provides basic guidelines regarding the utilization of multiple cropping systems to enhance functional biodiversity by associating two or more species that maximize productivity per area unit, suppress weeds, and reduce pest populations and phytopathogenic agents. The use of multiple cropping is a sustainable alternative, a prospective tool in assessing agricultural land use options and in the design of new cropping technologies to develop agroecosystems at eco-regional level. A synthetic indicator of the multiple crops' performance compared to the pure stands' components is the Land Equivalent Ratio (LER). In this context, we present an explanatory case study using experimental results related to the land utilization efficiency of clover – hybrid ryegrass mixtures with equal participation ratio. In the first growth cycle of second cropping year, similar values of LER were found in both red clover ploidy groups in mixtures with hybrid ryegrass: non-fertilized diploid cultivars - 1.28, respectively non-fertilized tetraploids - 1.31; and foliar fertilized diploid cultivars - 1.43, respectively tetraploids - 1.40. The annual average of LER for the second year presented values between 1.08 and 1.34 for both non-fertilized and foliar fertilized variants. The responsible factors for the better use of space were the mechanisms of interspecific competition for resources and the mutual grass–clover interactions. Multiple cropping systems have potential in the framework of sustainable agriculture by maximizing the system outputs (yields) and LER coefficients, and by minimizing inputs (fertilizers, herbicides, and pesticides), which finally leads to the diminishing of the environmental impact.

Key words: clover species, hybrid ryegrass, Land Equivalent Ratio, foliar fertilization, Leaf Area Index.

INTRODUCTION

The present paper provides basic guidelines of multiple crops utilization as a method of functional biodiversity amplification using species associations that maximize the productivity per unit of land area, suppress the risk of weeds growth and development, and reduces the pests and insects' populations. Furthermore, the multiple cropping is a *prospective instrument in evaluating arable land utilization options, and in designing new cropping technologies,* which provides sustainable cropping alternatives in the context of agroecosystems development at eco-regional level. A synthetic explicit indicator of multiple cropping agronomic performances compared to species' monocultures is the *Land Equivalent Ratio* (LER). In this paper, the case study presents the experimental results regarding the land utilization efficiency, forage yields, and canopy structure of red clover-hybrid ryegrass and white clover-hybrid ryegrass binary mixtures recorded between 2004 and 2006 in the ecological and edaphic conditions of the Targoviste Piedmont Plain.

Sustainable agriculture seeks the application of models and patterns encountered in nature to design agricultural production systems (Sullivan, 2001). The cropping practices that amplify the functional diversity and agroecosystem stability are as follows: farms' diversification, crop rotation, landschaft and *multiple crops*. Multiple crops show a number of experimentally demonstrated advantages, such as:

- widening of productivity capacity of the arable land by maximizing the time and space exploitation possibilities (Gliessman, 2006);

- suppression of weeds through niches pre-emption and interspecific competition for

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resources (Liebman and Dyck, 1993; Teasdale, 1998);

- complementarity of resources consumption from physiological, temporal and morphological points of view for the associated species (Dunea, 2002);

- superior yields due to the efficient utilization of available resources, canopy space and the mutual interactions between heterogeneous canopy components (Dunea, 2006);

- repellence of insects and diminishing of pests' proliferation (Altieri and Liebman, 1994).

The multiple crops are usually considered in low-input farming systems, both in developed and less developed countries to reduce weeds density and to maximize land use (Liebman and Dyck, 1993). The most known example of weed control is the use of cover crops (e.g. legume species) that protect and early cover the soil between the rows of cash crop or between the production cycles of the main crops (Aldrich, 1984; Bowen et al., 1986).

Multiple cropping systems ameliorate the yield stability due to more consistent yields (Fukai and Trenbath, 1993; Baumann, 2001), and optimize the use of available resources, thus minimizing the system's inputs cost (Keatings and Carberry, 1993). Multiple cropping systems have been successfully used to prevent erosion and soluble nutrients runoff, which diminishes the level of underground water contamination (Phatak, 1992). Cereal - legume multiple crops are among the most frequently used and most productive systems (Ofori and Stern, 1987). Although, multiple cropping is less frequently used in high-input agricultural systems, mixtures of cereals (such as barley, wheat, or oat) with forage legumes (such as white clover, red clover, or alfalfa) are common in mechanized temperate farming systems. The most relevant effect is the suppression of perennial weeds.

Maize-soybean multiple crops showed better yields than maize mono-crops (Moga et al., 1996). The soybean component adds valuable nitrogen to the soil and improves overall protein content of the resulting silage (Martin et al., 1990). Further, such intercrop system reduces weed growth allowing reductions in herbicides utilization. In Romania, past experience in multiple cropping included traditional intercropping arrangements (e.g. maize-bean, maize-peas, maize-pumpkin), sowed artificial grassland, forage systems, and anti-erosive and conservation agricultural systems. The most known example of intensive multiple cropping system is named "*borceag*". The fall type comprises wheat and forage peas (*Pisum arvense*). Spring "*borceag*" comprises two species: oats and spring forage peas (Moga et al., 1996).

Comparing with pure crop, multiple cropping systems bring faster propagation of canopy soil cover, improvement of Photosynthetically Active Radiation (PAR) absorbed, better competition with weeds, and better capture of available resources. However, multiple crops need to maintain at least the relative total (financial) yield, crop quality and labor efficiency of the pure crops (Vereijken and Kropff, 1996). The use of various clover species as cover crops gave promising results of weed control in cash crops (Den Hollander et al., 2007). Cover crops, intercrops, and "trap" crops bring benefits in terms of crop productivity and yield stability (Coaker, 1987; Altieri, 1994).

Two or more crops simultaneously grown on the same field must have adequate space to maximize cooperation and minimize interspecific competition. Five basic elements are required to design multiple cropping systems, as follows: selection of compatible and disease resistant cultivars (Liatukienė et al, 2013), spatial arrangement, plants' density, maturity period of the component species, and heterogeneous canopy architecture.

An efficient multiple cropping system requires 1) a detailed planning of the system, 2) sowing or planting at the optimal period for each associated species, 3) application of the proper fertilization scheme, 4) integrate control of pests and insects, and 5) efficient harvesting of each component species.

Planning refers to the optimal selection of species and cultivars (Schitea et al., 2007), water resources estimation, spatial arrangement and plants' density, sequence of operations in the growth season, required mechanized tillage and the forecasting of multiple crops' feasibility. The planning of multiple crops' fertilization is difficult because optimum levels must be ensured for all component species. In general, rates increased by 10-30% are recommended compared to the monocultures of components. Multiple crops influence the formation of component crops' yields (harvest index, thousand seed weight, the number of reproductive organs, the number of seeds etc.). In multiple cropping systems, weed suppression without affecting the cash crop in some degree is often difficult to achieve in practice (Dunea and Voican, 2006).

Compared to monocultures, multiple crops must maintain the economic yield, the product quality, and the labor efficiency at least at the same level. Multiple crop advantage is highlighted when LER is above unit (1), while numbers below this value show an inferiority of multiple crops as compared to monocultures. A value of 1.25 means an efficient use of land, the monocultures of the associated species requiring 25% more land to equal the total yield obtained in multiple crops. As such, a value of 0.75 indicates a disadvantage of the multiple cropping system, its yield representing 75% of the monocultures yields obtained on the same area unit.

In an experiment conducted 5 years to investigate hay yield and nitrogen harvest in binary smooth bromegrass mixtures with alfalfa and red clover, the LER values were higher in mixtures (e.g. 1.28 in both mixtures' types) compared with pure stands (Gökkuş et al.,1999). Sengul (2003) found that the LER values of grass mixtures were higher in both single and binary grass mixtures in presence of alfalfa (1.10, 1.22) and sainfoin (1.08, 1.11, respectively), than those of their pure stands. Maize – legumes intercrops increased forage quantity and quality and decrease requirements for protein supplements as compared with the maize monocultures (Javanmard et al., 2009). In Romanian Plain conditions, alfalfa and berseem clover mixtures showed yields of 7.98–11.91 t D.M. ha^{-1}, obtained in the first year of vegetation, as compared to alfalfa pure stands 4.00–4.86 t D.M. ha^{-1} (Zamfir et al., 2001). However, multiple cropping of berseem clover with barley did not show LER above unit (1), which indicated that there was no advantage of the intercrops over monocultures (Vasilakoglou and Dhima, 2008). Mutual grass–legume interactions stimulated acquisition of symbiotic and non-symbiotic nitrogen, and nitrogen efficient transformation into biomass compared to either monocultures. These effects of functional diversity contributed to productive and resource efficient agricultural grassland systems, the advantage being maximized in mixtures with 40–60% legumes (Nyfeler et al., 2011).

MATERIAL AND METHODS

One of the research focuses was to estimate the LER for red clover (*Trifolium pratense* L.), and white clover (*Trifolium repens* L.) mixtures with hybrid ryegrass (*Lolium hybridum* Hausskn).

The experimental trial was performed between 2004 and 2006, on pseudogleic brown alluvial soil in Targoviste Piedmont Plain, using a randomized block design with three replicates for each variant. The percentage of participation in mixtures was equal (50%) for both clover and grass components and the plots were sown on April 24, 2004. Red clover genotypes were tetraploid (Napoca-Tetra, Dacia-Tetra, and Vesna) and diploid (Flora, Roxana, and Start). White clover was included in the experiment using the Karina cultivar to observe the particular and contrasting aspects in terms of canopy architecture and soil cover compared to red clover. A tetraploid hybrid ryegrass cultivar (Zefir) was selected as accompanying grass to form an intensive forage production system (Schitea and Varga, 1995; Schitea et al., 2002).

The average canopy height was determined diagonally at four positions per plot. A quadrat frame of 0.50×0.50 m was used to harvest samples from each plot in two points. All samples were dried for 24 h at 80°C and weighed using a precision balance.

Representative subsamples were taken and separated in morphological components to determine the leaf area, which was measured using a digital area meter. PAR was monitored using a digital solarimeter with PAR sensor. Radiation use efficiencies (g D.M. MJ^{-1}) were calculated from the linear regressions between dry matter accumulation and absorbed PAR within mixed canopies.

In the second year of the experiments, foliar fertilizers ($N_{15}P_5K_{30}$ + 3 MgO + microelements) were applied in the fertilization variants (Ft) at several rates during the vegetation season, both in pure stands and grass-clover mixtures. Mt is the abbreviation of non-fertilized variants (control), while Ft is for foliar fertilized variants.

The calculation of the land equivalent ratio (LER) using the sum of yield ratios for each component species obtained in multiple crop and monoculture provides an estimation of the land use efficiency of the multiple cropping system (Eq.1).

$$L.E.R. = \frac{Species \quad A - multiple\ crop}{Species \quad A - monoculture} + \frac{Species \quad B - multiple\ crop}{Species \quad B - monoculture}$$

For a better characterization of LER, equation 1 was converted into a sum of the solar energy conversion ratios determined in mixture and in pure stands of the associated species (Eq.2).

$$L.E.R. = \frac{RUE_{clover} mixture \cdot PAR_{a\ clover} mixture}{RUE_{clover} pure \cdot PAR_{a\ clover} pure} + \frac{RUE_{ryegrass} mixture \cdot PAR_{a\ ryegrass} mixture}{RUE_{ryegrass} pure \cdot PAR_{a\ ryegrass} pure}$$

where: *PAR_a – absorbed Photosynthetically Active Radiation* [MJ^{-1} m^{-2}]
RUE – Radiation Use Efficiency of the species [g D.M. MJ^{-1} m^{-2}]

RESULTS AND DISCUSSIONS

The LER results presented in this paper were recorded during three years of experiments, respectively seven cutting cycles.

Three cuttings were performed each year in 2004 and 2005, and one in 2006, as follows: C1 – July 17 (84 Days after sowing), C2 – August 28 (42 DAR – Days after regrowth), C3 – November 6 (70 DAR), C4 – June 25 (105 DAR), C5 – August 23 (59 DAR), C6 – September 30 (39 DAR), and C7 – July 2 (98 DAR).

The comparisons of the observed differences between variants were performed using the Tukey HSD test (Honestly Significant Differences).

Mixtures with grasses provide higher amounts of dry matter and improved digestibility of the forage compared to red clover and white clover pure stands, at the expense of crude protein content and clover participation to yield formation per area unit. The effects of accompanying grass to the forage total yield and quality are higher in the first cycle, usually in June, when the grass component of the mixture is dominant compared to subsequent growth cycles. Experimental data have confirmed the superiority of grass–clover mixtures compared to the pure stands of component species in terms of land use efficiency, because of significantly improved RUE bioconversion and PAR absorption per unit of land area (Table 1).

Table 1. Land equivalent ratios of the clover-hybrid ryegrass mixtures (cv. Zefir) obtained in the cycles of production during three years (2004-2006) in Targoviste Piedmont Plain; Karina – white clover cultivar; non-fertilized (Mt) and foliar fertilized (Ft) variants; DAS – days after sowing; DAR – days after regrowth for subsequent cycle.

Growth cycles	Land utilization	Red clover tetraploids			Red clover diploids			White clover
		Vesna	Dacia-Tetra	Napoca-Tetra	Flora	Roxana	Start	Karina
C1 July 17 (84 DAS)	Clover	0.89	0.56	0.17	0.37	0.54	0.63	0.64
	Ryegrass	0.80	0.44	1.03	0.59	0.46	0.66	0.56
	L.E.R.	1.69	1.00	1.20	0.96	0.99	1.29	1.20
C2 August 28 (42 DAR)	Clover	1.32	0.71	0.90	1.08	1.00	1.03	0.79
	Ryegrass	0.18	0.63	0.75	0.71	0.59	0.77	0.81
	L.E.R.	1.49	1.34	1.65	1.79	1.59	1.79	1.60
C3 November 6 (70 DAR)	Clover	0.52	0.53	0.88	0.82	0.83	0.89	0.92
	Ryegrass	0.18	0.62	0.49	0.52	0.58	0.44	0.59
	L.E.R.	0.69	1.15	1.37	1.34	1.41	1.32	1.51
2004	Average L.E.R.	*1.29*	*1.16*	*1.41*	*1.36*	*1.33*	*1.47*	*1.44*
C4 – Mt June 25 (105 DAR)	Clover	0.49	0.76	0.55	0.64	0.6	0.55	0.39
	Ryegrass	0.71	0.65	0.77	0.62	0.78	0.64	1.02
	L.E.R.	1.2	1.41	1.32	1.25	1.39	1.19	1.41
C4 – Ft	Clover	0.39	0.44	0.49	0.44	0.39	0.5	0.48
	Ryegrass	1.03	0.81	1.04	1.01	0.92	1.02	1.25
	L.E.R.	1.42	1.25	1.53	1.45	1.31	1.52	1.73
C5 – Mt August 23 (59 DAR)	Clover	0.43	0.41	0.38	0.40	0.33	0.37	0.46
	Ryegrass	0.61	0.57	0.67	0.62	0.87	0.67	0.85
	L.E.R.	1.04	0.98	1.05	1.02	1.20	1.04	1.31
C5 – Ft	Clover	0.39	0.38	0.36	0.41	0.43	0.42	0.41
	Ryegrass	0.70	0.64	0.83	0.62	0.73	0.70	1.01
	L.E.R.	1.09	1.02	1.19	1.03	1.16	1.12	1.42
C6 – Mt September 30 (39 DAR)	Clover	0.59	0.58	0.46	0.51	0.53	0.62	0.41
	Ryegrass	0.41	0.39	0.46	0.82	0.89	0.78	0.50
	L.E.R.	1.00	0.97	0.92	1.33	1.42	1.40	0.91
C6 – Ft	Clover	0.57	0.52	0.40	0.49	0.53	0.57	0.44
	Ryegrass	0.40	0.46	0.48	0.80	0.88	0.80	0.47
	L.E.R.	0.97	0.98	0.88	1.29	1.41	1.37	0.91
2005 Mt	L.E.R. Mt	*1.08*	*1.12*	*1.10*	*1.20*	*1.34*	*1.21*	*1.21*
2005 Ft	L.E.R. Ft	*1.16*	*1.08*	*1.20*	*1.26*	*1.29*	*1.34*	*1.35*
C7 July, 2 (98 DAR)	Clover	0.60	0.69	0.95	0.41	0.43	0.62	0.23
	Ryegrass	0.66	0.79	0.87	0.80	0.61	0.84	0.83
	L.E.R.	1.26	1.48	1.81	1.21	1.04	1.46	1.06
2006	L.E.R.	*1.26*	*1.48*	*1.81*	*1.21*	*1.04*	*1.46*	*1.06*

In the first year of cropping, no fertilizers were applied to allow and assess the natural manifestation potential for each variant (clover pure stands, grass-clover mixtures, hybrid ryegrass pure stand). In the first production cycle (C1), red clover cultivars had various manifestations, from beneficial mutual interactions with hybrid ryegrass (Vesna and Start) to lower participation to ground cover due to hybrid ryegrass strong competition and their tardiness (Napoca and Flora). White clover had a fast development and performed well in association with hybrid ryegrass (Zefir cultivar).

Land equivalent ratio

In the first growth cycle of the sowing year (C1), LER varied from 0.96 (Flora) to 1.69 (Vesna) in red clover, and was 1.20 in white clover mixture. The next cycle (C2) showed the improvement of the LER in all variants ranging from 1.34 to 1.79 mainly due to the clover contribution as compared to the corresponding pure stands.

In the last cycle of the first year of cropping (C3), all red clovers cultivars showed LERs above unit (1.15-1.41), excepting Vesna cultivar that recorded 0.69. White clover had a LER of 1.51. The annual average of LERs recorded in the growth cycles of the first year of cropping showed a superior value for diploid cultivars (average of 1.38) as compared to tetraploid ones (1.28).

In the first growth cycle of the second cropping year (C4), both red clover ploidy groups showed similar LER values of the mixtures as follows: an average of 1.28 for diploid cultivars (Mt), and 1.31 for tetraploids, while foliar fertilized (Ft) variants recorded 1.43 for diploid mixtures with hybrid ryegrass, and 1.40 for tetraploid ones.

Analyzing the LER components of grass-red clover multiple crops, the same constant trend was observed for diploid red clover cultivars with averages of 0.6 (Mt) and 0.45 (Ft). The hybrid ryegrass contribution to LER was 0.68 (Mt), respectively 0.98 (Ft). In the tetraploid mixtures, red clover cultivars averaged 0.6 (Mt) and 0.44 (Ft) with LER component values of 0.71 (Mt) and 0.96 (Ft) for the hybrid ryegrass. Consequently, in the eco-climatic and edaphic conditions of the experiment in the second cropping year, it can be concluded that land use efficiency was not influenced by the genotype of red clover, the responsible factors for a better use of growth and development space being the mechanisms of interspecific competition for resources and hence the efficiency of these resources utilization. The mutual grass-clover interactions had also a significant influence depending on bio-morphological traits of the red clover cultivars (canopy architecture, tardiness, winterkill resistance etc.).

White clover mixture showed a different pattern of land use allowing the growth and development of hybrid ryegrass, but maintaining a sufficient clover content, due to its ecophysiological traits specific for undersown crops. White clover mixture reached the maximum values concerning the land use (1.73).

In C4, the ascending classification of the grass-clover mixtures based on LER values was as follows:

- Mt variants: Start, Vesna, Flora, Napoca-Tetra, Roxana, Dacia-Tetra, and Karina;
- Ft variants: Dacia Tetra, Roxana, Vesna, Flora, Start, Napoca-Tetra, and Karina.

Zefir hybrid ryegrass cultivar showed a strong competition capacity in the first growth cycle (C4). Foliar fertilization has amplified this trait, and has substantially modified its contribution to the mixtures' LER. The ratio of mixtures' components was relatively symmetrical in the non-fertilized variants, but foliar fertilizers led to LER values of grass component that were superior of hybrid ryegrass pure stand (0.81-1.25). However, at mixtures' overall level, foliar fertilization has not significantly influenced LER. Tukey HSD test did not show a statistical significance of the difference between Mt and Ft variants (LSD 5%: 0.13).

In the subsequent production cycle (C5), LER values of the mixtures were superior (Mt: 1.02-1.20; Ft: 1.02-1.19) compared to pure stands of components showing an increase of the clover component contribution, excepting non-fertilized mixture of Dacia-Tetra (0.98). The last growth cycle of 2005

(C6) showed the most contrasting behaviors between the ploidy groups, tetraploids recording small LER values (≤1) in both fertilization variants (Mt and Ft), respectively diploids with LER values ranging from 1.33 to 1.42 (Mt), and 1.29 to 1.41 (Ft). The annual average of LER for the second production year (considered the most productive year for red clover) presented values between 1.08 (Vesna) and 1.34 (Roxana) for Mt variants, and between 1.08 (Dacia-Tetra) and 1.34 (Start) – Ft variants. High yielding cultivars in pure stands (e.g. Vesna, Flora) recorded smaller annual average LERs.

The LERs in the first growth cycle of third cropping (C7) year were influenced by the persistence characteristics of the clover cultivars. Ground cover in early spring was 54.33% for tetraploid cultivars (CV=43.25%), and 67% for diploid cultivars (CV=6.83%) in pure stands. An average of 27% clover ground cover was recorded both for tetraploid cultivars (CV=36.47%), and for diploid cultivars (CV=16.97%) in mixtures with hybrid ryegrass (Dunea, 2008). Winter killing occurred significantly in the less adapted cultivars (Napoca-Tetra and Dacia-Tetra). Consequently, these cultivars showed LER values of 1.81 (Napoca-Tetra) and 1.48 (Dacia-Tetra). The mixtures showed better ground cover compared to red clover pure stands, with a superior contribution of the hybrid ryegrass that insured a closed stand and maintained clover component in acceptable limits. White clover had the lowest value (0.23) in mixture's LER.

Forage yields

In the context of previous experiments (Moga et al., 1996), the global results obtained in Targoviste Piedmont Plain showed that the maximum average yield (17.64 t D.M. ha^{-1}) was recorded in the second year of cropping by foliar fertilized diploid cultivars in mixtures with hybrid ryegrass (Table 2). During the 2004-2005 years, average yields were 9.2 t ha^{-1} in red clover pure stands without fertilization and 11.3 t ha^{-1} with foliar fertilization, while averages values of 14 t ha^{-1} without fertilizers and 15.7 t ha^{-1} with foliar fertilizers were recorded in grass-red clover mixtures.

Table 2. Annual production (t D.M. ha^{-1}) of red clover's pure stands and mixtures with hybrid ryegrass recorded in Targoviste Piedmont Plain (2004 – sowing year; 2005 – the year of red clover maximum productivity) for non-fertilized (Mt) and foliar fertilized variants (Ft)

Cultivars	Red clover pure stands		Red clover + hybrid ryegrass mixtures	
	Mt	Ft	Mt	Ft
Napoca-Tetra	9.33	12.25	12.83	16.86
Dacia-Tetra	8.67	12.94	12.53	14.58
Vesna	10.84	16.85	12.88	17.50
Average of Tetraploid cultivars in 2005	9.61	14.01	12.74	16.31
CV%	*11.57*	*17.70*	*1.48*	*9.40*
Average of Tetraploid cultivars in 2004	8.12	-	14.52	-
CV%	*26.54*	-	*11.67*	-
Roxana	9.08	14.00	14.92	17.00
Flora	11.22	15.82	14.31	18.01
Start	10.22	13.12	13.62	17.93
Average of Diploid cultivars in 2005	10.17	14.31	14.28	17.64
CV%	*10.52*	*9.62*	*4.55*	*3.18*
Average of Diploid cultivars in 2005	8.89	-	14.56	-
CV%	*14.55*	-	*7.21*	-
Average of 2004-2005 interval	9.19	11.33	14.02	15.75

The tetraploids' pure stands (8.12 t D.M. ha^{-1}) in the sowing year produced the lowest yield. Foliar fertilization applications provided yield increasing of 4.4 t ha^{-1} for tetraploid pure stands and 4.14 t ha^{-1} for diploids ones as compared to non-fertilized variants. The yield increasing in mixtures showed gains of 3.57 t ha^{-1} in tetraploids, and 3.36 t ha^{-1} in diploids compared to control variants (Mt).

It is important to mention that non-fertilized mixtures presented a decrease of dry matter yield between first year and second year, with 1.78 t ha^{-1} (tetraploids) and 0.28 t ha^{-1} (diploids).

In the second year, the annual yield of forage variants based on the binary associations of hybrid ryegrass and red clover cultivars showed significant yield gains compared to pure stands of component species.

Multiple comparisons showed statistical significance of these differences:

• Mt variants: Mixture 4n (12.74 t ha^{-1}) – pure stand 4n (9.61 t ha^{-1}): + 3.13** t ha^{-1} (LSD 1% : 2.99);

• Mt variants: Mixture 2n (14.28 t ha^{-1}) – pure stand 2n (10.17 t ha^{-1}): + 4.11** t ha^{-1} (LSD 1%: 3.33);

• Ft variants: Mixture 4n (16.31 t ha^{-1}) – pure stand 4n (14.01 t ha^{-1}): + 2.3 t ha^{-1} (LSD 5% : 4.67);

• Ft variants: Mixture 2n (17.64 t ha^{-1}) – pure stand 2n (14.31 t ha^{-1}): + 3.33* t ha^{-1} (LSD 5% : 2.38).

Canopy architecture (average height and LAI)

In the plants' phytosociological associations (cultivated species-weeds, legume-grass mixtures, multiple crops etc.), the light interception in mixed canopy is influenced by the leaf area index (LAI), the positioning height of leaf area and the light absorption characteristics of leaves for each component species.

A superior position of the leaf area inside the canopy ensures higher absorption and reflectance of solar incident radiation compared to underneath layers. Light absorption of crops depends on the optical properties, thickness, and angular distribution of leaves. This distribution determines the amount of radiation absorbed per leaf area unit.

Figure 1 presents the average height dynamics of red clover-hybrid ryegrass mixed canopies during the growth cycles of the second year of cropping. Hybrid ryegrass exceeded the average height of red clover cultivars with 25 cm in C4, 8 cm in C5 and was shorter with 2.5-3 cm in C6.

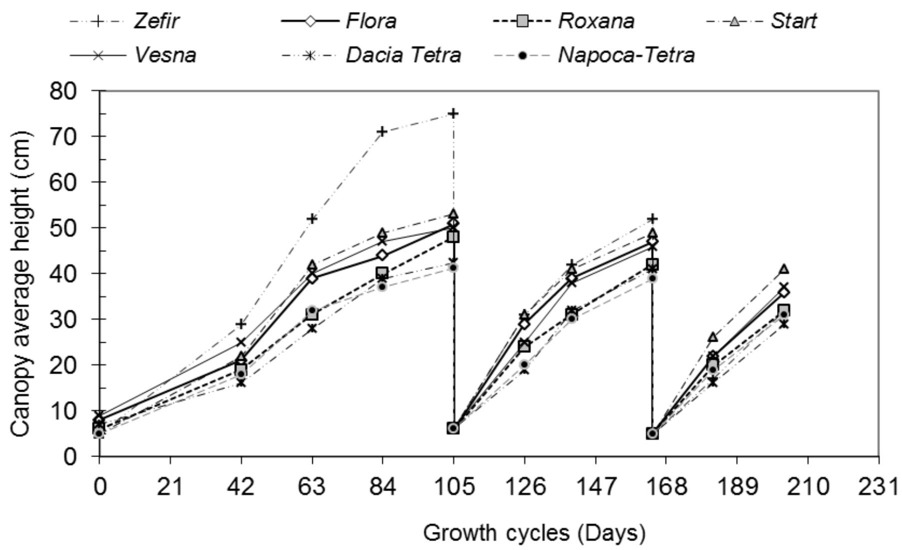

Figure 1. Average height of the red clover-hybrid ryegrass mixed canopy in the second year of cropping when three cuttings (C4, C5, and C6) were performed – Ft variants; Zefir – tetraploid hybrid ryegrass

In red clover pure stands, the average height of the homogenous canopy (Figure 2) was 55 cm in C4, 45 cm in C5, and 35 cm in C6. Start diploid cultivar was the tallest in all the growth periods due to its specific biometric characteristics.

In red clover, the size of leaves was dependent on their position in the canopy height layers, the smallest ones being apical and basal leaves, and respectively the largest ones being the leaves situated in an intermediate position within the canopy. The number of leaves, their areas, and their position on the plants had influence on LAI, and consequently on PAR absorption. Leaf area distribution of red clover in the mixed canopy was asymmetric, the maximum leaf area values being observed between 64 and 72% of the total height of the canopy. The maximum leaf areas of the hybrid ryegrass were positioned between 38 to 45% of the canopy height. LAI values were positively correlated with dry matter yield per area unit.

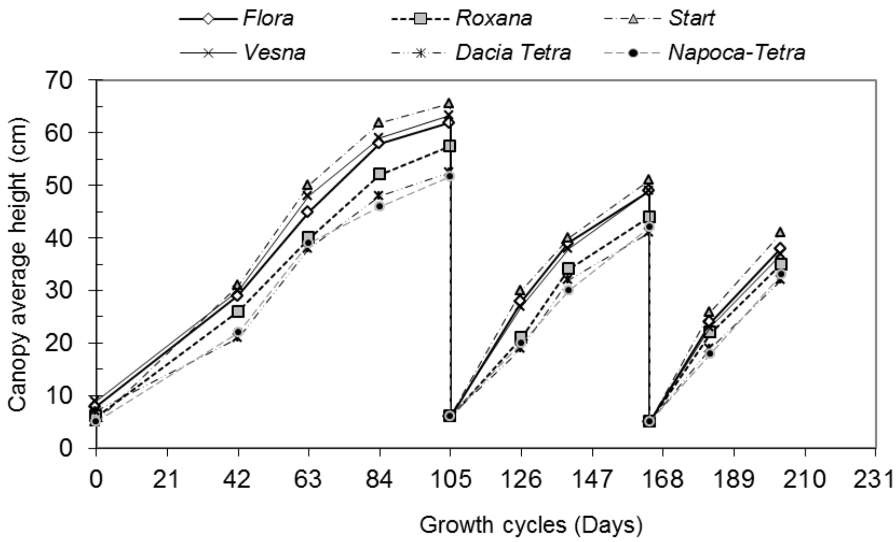

Figure 2. Average height of the red clover homogenous canopy in the second year of cropping with three cuttings regime (C4, C5, and C6) – Ft variants; Vesna, Dacia-Tetra and Napoca-Tetra – tetraploid red clover cultivars; Start, Roxana and Flora – diploid cultivars

Table 3 presents the cumulated LAI values of the mixed canopies recorded at the cutting moments of each growth cycle of the second year of cropping.

The experimental data showed that foliar fertilization has improved significantly the cumulated LAI of red clover-ryegrass mixtures in C4. The other two growth cycles had only three (C5) and, respectively two significant variants (C6) for Ft-Mt differences.

In C4, the average cumulated LAI of Mt variants relied on an approximate contribution of 40% tetraploid red clover and 60% ryegrass, respectively 45% diploids and 55% ryegrass.

Because of foliar fertilization, the contribution of red clover in the mixed canopy increased in tetraploid variants (42%), and slightly decreased in diploids (44%). The contribution of Zefir cultivar to the cumulated LAI was highest in the white clover mixture ($LAI_{h.ryegrass}$: 4.7 – Mt, and 4.97 – Ft), due the low competition capacity of Karina cultivar in this type of mixture ($LAI_{w.clover}$: 0.69 – Mt, and 1.03 – Ft).

Table 3. Influence of foliar fertilization ($N_{15}P_5K_{30}$ + 3 MgO) on cumulated Leaf Area Index (clover and hybrid ryegrass) of mixtures in the second year of production; multiple range tests of non-fertilized (Mt) and fertilized (Ft) variants were performed with Tukey HSD (*LSD 5%; **LSD 1%; ***LSD 0.1% for Ft - Mt differences).

Growth cycles	LAI (m^2m^{-2}) Red clover tetraploids + hybrid ryegrass			LAI (m^2m^{-2}) Red clover diploids + hybrid ryegrass			LAI (m^2m^{-2}) White clover + hybrid ryegrass
	Vesna	Dacia-Tetra	Napoca-Tetra	Flora	Roxana	Start	Karina
C4 – Mt June 25 (105 DAR)	6.09	5.43	5.26	6.2	5.14	5.88	5.39
C4 – Ft	*6.95***	*6.71****	*6.19***	*6.93***	*6.48****	*6.58***	*6.02**
C5 – Mt August 23 (59 DAR)	3.01	2.66	2.24	2.80	2.78	2.86	3.05
C5 – Ft	*3.25*	*3.12***	*3.18****	*3.32****	*2.94*	*2.97*	*3.32**
C6 – Mt September 30 (39 DAR)	1.49	1.38	1.24	1.53	1.44	1.41	1.97
C6 – Ft	*1.71*	*1.60*	*1.39*	*2.01***	*1.82**	*1.67*	*2.12*

CONCLUSIONS

The clover-hybrid ryegrass mixtures showed advantages compared to the pure stands of the components in terms of forage yield, light interception, and utilization of resources. Consequently, land use was superior, and fodder production per area unit proportionally increased depending on cultivar, proper application of foliar fertilizers, and growth cycle.

LER calculations provided reliable information for the evaluation of mixtures' performances. The annual averages of LERs obtained in Targoviste Piedmont Plain varied, showing an average of 1.38 for diploid cultivars and 1.28 for tetraploids in the first year of cropping, and values between 1.08 and 1.34 for both Mt and Ft variants in the second production year. White clover had LERs of 1.44 in the first year, and 1.21 (Mt) and 1.35 (Ft) in the second year.

In the first two years interval the average yields were 9.2 t ha^{-1} in red clover pure stands (Mt) and 11.3 t ha^{-1} (Ft). Averages values of 14 t ha^{-1} (Mt) and 15.7 t ha^{-1} (Ft) were recorded in hybrid ryegrass-red clover mixtures. Cumulated LAI measured in red clover mixtures reached maximum in the first growth cycle of the second year from 5.14 to 6.2 (Mt) and 6.19 to 6.95 (Ft). In the same growth cycle, white clover mixture showed LAI values of 5.39 (Mt) and 6.02 (Ft).

The experimental results confirmed that clover-hybrid ryegrass mixtures are among the most productive forage systems, showing a positive response to foliar fertilization. Hybrid ryegrass association with less vigorous and productive clover cultivars in mixtures ensured a reliable yield and proper ground cover minimizing the empty spaces that occurred in clover pure stands.

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