# Forage legumes and grasses: more advantages in pure crop rotation or intercropping?

**Vargiu M., Spanu E., Mulè P.**

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**Forage resources and ecosystem services provided by Mountain and Mediterranean grasslands and rangelands**

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# Forage legumes and grasses: more advantages in pure crop rotation or intercropping?

**M. Vargiu*, E. Spanu and P. Mulè**

Agris Sardegna, Dipartimento per la Ricerca nelle Produzioni Vegetali,
Viale Trieste 111, 09123 Cagliari (Italy)
*e-mail: mvargiu@agrisricerca.it

**Abstract.** Intercropping of grasses and legumes could represent a viable alternative to rotation because of the ready availability of nitrogen and the complementary distribution of the aerial and root systems. This paper reports two years (2012-2013) forage yield results of some legumes (berseem and squarrose clover, hairy vetch and burr medic) and grasses (ryegrass and oats) grown as pure crops as well as intercrops. In the two years the annual dry matter production was 5 t $ha^{-1}$ but seasonal yield was very different for each species due to inter-annual weather variability. In the second year, except for vetch, that showed a rather stable production, forage yield was delayed increasing hay production. In the first year, total yield of intercropping (except for ryegrass/clover mixture) was often higher than pure crop (Land Equivalent Ratio >1). Seasonal production was instead variable: the mixtures berseem/grass, medic/grass and squarrose/oats for pasture, vetch/grass and squarrose/oats for hay were more favourable than pure crops. In the second year, mixtures was less convenient (LER<1); benefits were evidenced in some case (medic/grasses, berseem/oats and squarrose/oats) only for hay.

**Keywords.** Forage yield – Intercropping – Rotation – Legumes – Grasses – Sustainable agriculture.

***Légumineuses fourragères et graminées : avantage aux cultures pures ou aux associations ?***

***Résumé.*** *Des implantations annuelles de cultures mixtes de graminées et légumineuses pourraient représenter une alternative à des rotations de cultures pures, jouant sur la modification des disponibilités d'azote et la complémentarité de distribution des systèmes aérien et racinaire. Cette étude présente les résultats de deux années (2012 - 2013) sur le rendement fourrager de légumineuses (trèfle d'Alexandrie et trèfle écailleux, vesce velue et luzerne annuelle) et de graminées (ray-grass et avoine) cultivées en mélange ou en culture pure. Durant les deux années la production annuelle a été 5 t $ha^{-1}$ de matière sèche mais, influencée par les conditions météorologiques, le rendement saisonnier a été très différent pour chaque espèce. Durant la deuxième année, à l'exception de la vesce plutôt stable, on a observé un retard de production et, par conséquent, un rendement supérieur en foin. Dans la première année, le rendement total de la culture associée (sauf pour les associations ray-grass/trèfle) a été souvent plus élevé que la culture pure (LER>1). La production saisonnière a été variable : les mélanges trèfle d'Alexandrie/graminées, luzerne/graminées et trèfle écailleux/avoine pour le pâturage et les mélanges vesce/graminées et trèfle écailleux/avoine pour le foin ont été plus favorables que les cultures pures. La deuxième année, les associations ont été moins productives (LER <1); des avantages ont été obtenus seulement dans certains cas (luzerne/graminées, trèfle d'Alexandrie/avoine et trèfle écailleux/avoine) uniquement pour le foin.*

***Mots-clés.*** *Production fourragère – Association – Rotation – Légumineuses – Graminées – Agriculture durable.*

## I – Introduction

The intensive agriculture even if increases yield per hectare may cause serious environmental problems, principally due to the use of chemical and to overexploitation of soil. According to the Common Agricultural Policy guidelines, some rational agronomic techniques, like crop rotations and the use of legumes, could allow to mitigate the impact of agriculture by preserving soil fertility.

Legumes, in mixtures or rotation with grasses, as well as an important source of vegetable proteins, play a central role for the forage systems sustainability especially for the nitrogen enrichment of soils (Giambalvo *et al*., 2011). A large debate if grass/legume intercropping could be a valid alternative to pure crop rotation is still under way (Willey, 1979; Mariotti *et al*., 2006; Tuna *et al*., 2007).

Intercropping is the agricultural practice of cultivating two or more crops in the same space at the same time (Lithourgidis *et al*., 2011); the readily available nitrogen of legume's rhizobia and the different spatial distribution of root and air systems could influence a better use of resources (water, nutrients, radiation) than pure stand crop rotation.

This trial takes place in a Mediterranean environment, where drought summer conditions oblige to use annual forage species, with the aim to test the behaviour of several grasses and legumes sown and managed in "intercropping" and "rotation".

The paper reports the forage yield data of the first two years. In the long period it will be possible to deduce the implications of these managements on soil fertility.

## II – Materials and methods

The experiment is carried out in Southern Sardinia, near Cagliari (39°10' lat N, 150 m a.s.l.) on a soil classified as *Typic Calcixerept* according to Soil Taxonomy (USDA, 2010). Long term rainfall is 500 mm, irregularly distributed from October to May. Winter temperatures seldom reach 0 °C; average maximum temperature is 32°C in July.

Several annual grasses and legumes (Table 1) are settled in a forage system for grazing in winter and hay yield in spring, in order to test some stable intercropping (sown every year in the same plot) and the respective pure stand crop in annual rotation.

**Table 1. List of species in intercropping and pure stand. Seed rates in brackets refer to pure stand; the rate is halved in intercropping**

| | |
|---|---|
| 1 - Squarrose clover -*Trifolium squarrosum* L. (25 kg $ha^{-1}$) | 3 - Hairy vetch - *Vicia villosa* Roth (160 kg $ha^{-1}$) |
| 2 - Berseem clover - *Trifolium alexandrinum* L. (25 kg $ha^{-1}$) | 4 - Burr medic - *Medicago polymorpha* L. (25 kg $ha^{-1}$) |
| | 5 - Ryegrass - *Lolium multiflorum* Lam. (25 kg $ha^{-1}$) |
| | 6 - Oats - *Avena sativa* L. (160 kg $ha^{-1}$) |

The experimental design was a randomized block with 3 replications. In both years (2011-2012) sowing took place in mid-November, after P-fertilization (150 kg $ha^{-1}$ of $P_2O_5$), in plots of 14 $m^2$. Grasses in pure stand were fertilized with 40 units of nitrogen after each utilization.

The forage yield was evaluated weighting the herbage mechanically cut 10 cm above soil. All 500 g sub-samples were oven-dried for dry matter percentage at 65°C for three days. Mixture samples were previously botanically partitioned.

Productive efficiency of intercropping was determined with the land equivalent ratio (LER) (Mead and Willey, 1980; Willey and Rao, 1980), an index that defines the relative land area required by monocrops to produce the same yield of intercrops.

## III – Results and discussion

Total rainfall was 387 mm in 2012 and 510 in 2013 with remarkable differences in distribution. In 2013 the mean temperature in November, month of sowing, was 3°C lower than in 2012. Oppositely, in 2013 winter was colder and spring rainfall was higher than 2012 (Fig. 1).

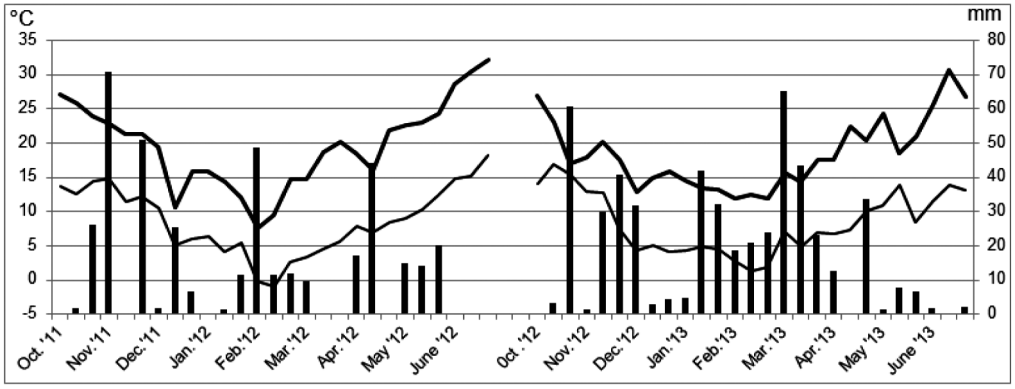


**Fig. 1. Weather recording in the two years (lines refer to maximum and minimum temperatures, bars to rainfall).**

The winter utilization, before the spring hay cutting, varied from one in vetch crops to four in berseem, according to the crops development.

In both years forage yield average of the experimental field was about 5 t ha$^{-1}$ (Table 2) but, while in the first year the production was balanced between winter (58%) and spring (42%), in the second year, when the emergence and development of crops were slow, it was predominant in spring (77%). Vetch in both years, as winter (pasture) or hay (spring), alone and intercropped, had a rather stable production.

**Table 2. Total production (t ha$^{-1}$) in the two years (in brackets legume percentage of intercropping), hay yield percentage and LER of total production**

| Intercropping and pure stand of different species | Total yield | | Hay % | | LER | |
|---|---|---|---|---|---|---|
| | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 |
| *Vicia / Lolium* | 5.5 A-C (80) | 5.0 C-F (56) | 80 | 76 | 1.00 | 0.89 |
| *Vicia / Avena* | 5.4 A-C (58) | 4.6 E-H (40) | 72 | 68 | 1.04 | 0.73 |
| *Trifolium squarrosum / Lolium* | 3.6 D (53) | 4.7 E-H (58) | 46 | 91 | 0.81 | 0.68 |
| *Trifolium squarrosum / Avena* | 4.8 B-D (53) | 7.2 AB (25) | 43 | 83 | 1.17 | 0.94 |
| *Trifolium alexandrinum / Lolium* | 4.8 B-D (53) | 3.7 F-I (24) | 41 | 90 | 0.94 | 0.72 |
| *Trifolium alexandrinum / Avena* | 5.2 A-D (60) | 6.4 B-E (10) | 39 | 79 | 1.10 | 0.95 |
| *Medicago / Lolium* | 5.5 A-C (66) | 3.2 F-I (42) | 13 | 74 | 1.08 | 0.84 |
| *Medicago / Avena* | 5.5 A-C (48) | 7.0 A-C (3) | 12 | 72 | 1.14 | 0.94 |
| *Vicia villosa* | 5.4 AB | 4.8 D-G | 65 | 62 | | |
| *Trifolium squarrosum* | 3.6 C | 6.7 A-C | 47 | 95 | | |
| *Trifolium alexandrinum* | 4.6 BC | 2.8 G-I | 48 | 86 | | |
| *Medicago polymorpha* | 4.7 B-D | 2.3 I | – | 56 | | |
| *Lolium multiflorum* | 6.2 A | 7.1 AB | 54 | 77 | | |
| *Avena sativa* | 5.0 A-D | 8.0 A | 33 | 65 | | |

Means followed by the same letters are not significantly different at P = 0.01 (Duncan test).

***Intercropping vs pure stand*** – In the first year, total yield of intercrops was often superior (excepted for ryegrass/clover mixtures) than pure crops (LER >1) but seasonal trends were variable: while intercropping for vetch was more convenient in spring, for berseem was more convenient in winter; squarrose intercropping with oats was superior in all seasons but never with raygrass; burr medic was more convenient in mixtures than pure crops in winter, but it did not regrowth for hay. In the second year instead, intercropping were always less convenient (LER <1) with the only exception of benefits evidenced for hay in some mixtures (burr medic/grasses, berseem/oat and squarrose/oat).

***2012 (1st year)***

• Pure stand – Dry matter yield ranged from 6.2 t $ha^{-1}$ in ryegrass to 3.6 t $ha^{-1}$ in squarrose clover. Burr medic produced the most amount of pasture, but did not have any appreciable regrowth for hay. Vetch and ryegrass (3.5 and 3.3 t $ha^{-1}$, respectively) had the significantly highest hay yield.

• Intercropping – Productive differences between intercrops were less than pure crops. Annual yield was not significantly different (average 5.16 t $ha^{-1}$) except for squarrose/ryegrass that had the lowest yield (3.6 t $ha^{-1}$). Vetch was highly competitive with ryegrass, contributing 80% to the mixture composition, but less with oats (contribute 58%) (Table 2). Pasture yield was the highest for burr medic/grasses (4.8 t $ha^{-1}$) and the lowest for vetch/grasses (1.1 – 1.5 t $ha^{-1}$). Vetch showed a high competitiveness *vs* ryegrass since the winter season. In the flowering period burr medic ceased its growth and the mixtures with grasses showed the poorest yields. Vetch/grasses mixtures had the highest production of hay.

***2013 (2nd year)***

• Pure stand – Squarrose clover and the two grasses showed the highest total and hay yield (average of 7.3 and 5.7 t $ha^{-1}$ respectively), burr medic had the lowest one (2.3 and 1,3 t $ha^{-1}$). Oats showed also the highest pasture yield (2.8 t $ha^{-1}$) while squarrose clover had the lowest one (0.3 t $ha^{-1}$). Vetch, berseem and burr medic had the lowest hay yield (average of 2.2 t $ha^{-1}$).

• Intercropping – Oats was very competitive and its mixtures (except for vetch) reached the highest production despite the nearly disappearance of legumes. Legumes/ryegrass mixtures, on the contrary, achieved a more balanced floristic composition. Vetch was less competitive than the first year, with a contribution on total yield of 56% with ryegrass and 40% with oats.

## IV – Conclusions

It seems that forage production is more affected by the weather conditions than the cropping techniques. In the second year a cold winter and a rainy spring determined a slow emergence and development of crops delaying forage production to increase hay yield. Vetch showed the greatest productive stability and a good floristic balance in mixture. Oppositely, the other species showed a greater variability as regards the annual dry matter yield, seasonal production and floristic composition of mixtures. LER values calculated with the collected data did not allow to assess the superiority of one of the two alternatives under investigation and point out the necessity to continue the trial for more years in order to obtain additional information.

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