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Evaluation of the competition between alfalfa and sainfoin sown in mixture

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Abstract. Alfalfa and sainfoin are pluriannual forage legumes that are well adapted to the agronomic conditions of NE Spain. However the persistence of sainfoin decreased when sown with alfalfa in mixture. It could be attributed to the fact that the cutting frequency was more suitable for alfalfa. In order to evaluate the persistence of sainfoin in mixture, the evolution of the annual forage yield in these species was compared, when sown in pure stands or using two types of mixtures, on alternate rows or mixed on the same row. Two harvesting rates were established, one that was most suited to alfalfa and the other to sainfoin. The study was conducted in rainfed conditions in Badules (Teruel) and under irrigation in Zaragoza during 2011-2013. The results confirm the lower yields and persistence of sainfoin when mixed with alfalfa under irrigation, which could be attributed to the allelopathic effects of alfalfa on sainfoin. There is no evidence of allelopathic phenomena arising in rainfed conditions in the two sowing modes employed. Cutting frequency had no influence on the occurrence of allelopathic phenomena.

Keywords. *Medicago sativa* L. **–** *Onobrychis viciifolia* Scop. **–** Dry matter **–** Crude protein **–** Allelopathy.

Évaluation de la compétition entre la luzerne et le sainfoin semés en mélange

Résumé. *La luzerne et le sainfoin sont des légumineuses fourragères pluriannuelles bien adaptées aux conditions agronomiques du nord-est de l'Espagne. Il a été constaté que la persistance du sainfoin diminue quand il est semé en mélange avec la luzerne. Cela est généralement attribué à la fréquence de coupes du fourrage, qui serait plus adaptée à la pousse de la luzerne. L'objectif de cette étude était d'évaluer la persistance du sainfoin, et le rendement annuel des fourrages obtenus à partir de cultures pures de luzerne et de sainfoin ou des mélanges luzerne-sainfoin. Deux types de mélanges ont été testés : les deux espèces ont été semées en lignes alternées ou mélangées dans la même ligne. Les parcelles ont été coupées à deux stades de maturité de la luzerne, début de floraison ou pleine floraison. L'étude a été réalisée en conditions naturelles à Badules (Espagne) ou en irrigation à Saragosse (Espagne) pendant la période 2011-2013. Sous irrigation, le rendement et la persistance du sainfoin ont été plus faibles dans les mélanges luzerne-sainfoin. Ces résultats peuvent être attribués aux effets allélopathiques de la luzerne sur le sainfoin. Par ailleurs, en conditions naturelles, les effets allélopathiques n'ont pas été mis en évidence.*

Mots-clés. Medicago sativa *L.* **–** Onobrychis viciifolia *Scop.* **–** *Matière sèche – Protéine – Allopathie.*

I – Introduction

Alfalfa (*Medicago sativa* L.) and sainfoin (*Onobrychis viciifolia* Scop.) are pluriannual forage legumes that are well adapted to the agronomic conditions of NE Spain. They are particularly valued for their yield, their ability to restore soil fertility and their feed value (Aufrère *et al*., 2013). Alfalfa is furthermore characterized by the proportional distribution of its annual forage yield and its persistence, however it has the disadvantage that it causes bloating in animals; for sainfoin most of its forage yield is obtained from the first cut in spring, used for hay-making, and it is val-

ued for its hardiness and not-bloating qualities. Given these complementing characteristics, it has been suggested that both species should be included in meadows in the Ebro valley (Hycka and Benítez-Sidón, 1979; Delgado *et al*., 2009). However persistence of sainfoin decreases when sown with alfalfa in a mixture and this has been attributed to the cutting frequency at the start of blooming in alfalfa (Hycka and Benítez-Sidón, 1979; Delgado *et al*., 2009).This practice may be indirectly detrimental to the persistence of sainfoin since it blooms later than alfalfa and its optimal use is recommended at full bloom (Koch *et al*., 1972; Borreani *et al*., 2003), furthermore this cutting frequency gives the plant less time to recover its nutrient reserves.

The lack of persistence of sainfoin when sown with alfalfa may also be due to allelopathic phenomena between the two species. Both alfalfa and sainfoin display strong allelopathic effects with other species (Chung and Miller, 1995; Li, 2009). Chocarro y Lloveras (2012) compared allelopathic effects between alfalfa and sainfoin, finding that alfalfa has a greater allelopathic effect on sainfoin, which may be one of the causes for the rapid disappearance of sainfoin in meadows that also contain alfalfa. In order to assess the persistence of sainfoin in a mixture, the species dynamics, in terms of annual forage yield, was compared when sown in pure stands and using two types of mixtures, on alternate rows and mixed in the same row, in two standard sites, under irrigation and in rainfed high lands.

II – Materials and methods

The study was conducted in rainfed conditions in Badules (41°9'N; 11°15'W, altitude 930 m a.s.l.) and under irrigation in Zaragoza (41°3'N; 0°47'W, altitude 225 m a.s.l.) during 2011-2013. In Badules climatic and edaphologic conditions showed monthly mean temperatures of 8.9ºC min and 18.5ºC max, annual precipitations of 320.6 mm, loam soil, salinity 0.2 CE (1:5 dδ/m), pH (H_2O) 8.5, P (Olsen) 18 mg/kg, K (extracted in NH_4NO_3) 250 mg/kg and organic matter 2.33%. Conditions in Zaragoza were monthly mean temperatures of 21.4ºC max and 8.1ºC min, annual precipitations of 245.7 mm, silty-loam soil, salinity 0.24 CE (1:5 dδ/m), pH (H_2O) 8.24, P (Olsen) 7 mg/kg, K (extracted in NH_4NO_3) 134 mg/kg and organic matter 1.99%.

Two cultivars of alfalfa were tested: 'Tierra de Campos', under rainfed conditions and 'Aragón' under irrigation, and one "two-cut" type sainfoin cultivar from Reznos (Soria). The cultivars were sown in plots of 5 x 2 m, in pure stands or using two types of mixtures, on alternate rows and mixed in the same row, with two cutting frequencies: alfalfa at early bloom and at full bloom, in four replications. Sowing took place on 11 March 2011 in Badules and 21 October 2010 in Zaragoza, using, for the pure stands of alfalfa a sowing rate of 15 kg ha^{-1} in rainfed conditions and 30 kg ha^{-1} under irrigation, and 80 kg ha^{-1} and 100 kg ha^{-1} respectively for sainfoin. The mixture comprised 50% seed density of both species in each of the conditions. An N-P-K basic dressing of 20-37.5-37.5 kg ha^{-1} in rainfed conditions and 40-75-75 kg ha^{-1} in irrigated conditions was applied the first year and both quantities were replicate in winter every two years in rainfed conditions and every year in irrigated conditions.

Dry matter (DM) was obtained by cutting two 0.5 m^2 per plot and drying in a forced ventilation stove at 60ºC until a constant weight was achieved. Dry samples were used to determine crude protein (CP) contents, evaluated by the Dumas method (AOAC, 1990) and neutral detergent fibre (NDF), evaluated by the Van Soest method (Van Soest *et al.,* 1991). Mortality rate is presented as the percentage of dead plants at the end of the trial.

The results underwent a variance analysis according to a split-plot model, considering "species" on the main plot and "cutting frequency" on the split-plot. The statistical analysis was performed using the ANOVA procedure of the SAS statistical package (SAS, 2004), considering the cutting date as treatment. Comparison of means was performed by the LSD test. The percentages were arcsine-transformed prior to statistical analysis.

III – Results and discussion

Table 1 shows the mean annual DM yield and CP and NDF contents in the first three productive years under irrigation and two years in rainfed conditions (the sowing year has not been considered as productive given that the establishment of the trials in these conditions is a slow process).

Table 1. Annual dry matter yield (DM), crude protein (CP) and neutral detergent fibre content (NDF), three years mean under irrigation and two years mean in rained conditions. In brackets, the percentage of alfalfa (L) in the mixture

Location	Zaragoza (irrigation)			Badules (rainfed)		
	DM kg/ha	%CP	%NDF	DM kg/ha	% CP	%NDF
Species						
Alfalfa on pure stand	11931a	20.4 a	41.0 b	3964 ab	19.7 a	37.9 a
Sainfoin on pure stand	9456 b	17.8 c	43.1 a	4292 a	16.1 c	38.0 a
Alfalfa and sainfoin on alternate rows	11675 (87.9% L)	19.9 b	41.5 b	3857 b a (61.9% L)	18.3 b	37.9 a
Alfalfa and sainfoin on mixed rows	12043 a (89.6% L)	19.9 b	41.6 b	3763 b (66.3% L)	18.6 b	37.9 a
Species significance	***	***	**	*	***	NS
Cutting frequency						
Early bloom of alfalfa	11453 a (90.4% L)	19.9 a	41.1 b	3752 b (68.5% L)	19.0 a	37.0 b
Full bloom of alfalfa	11099 a (87.0% L)	19.1 b	42.5 a	4186 a (59.7% L)	17.4 b	38.5 a
Cutting frecuency significance	NS	***	***	**	***	***
Species x Cutting frequency interaction	NS	**	NS	NS	NS	NS

* P<0.05, ** P<0.01, *** P<0.001, NS: non significant. Different letters within each column indicate P<0.05%.

The results show that alfalfa is more productive (P<0.001) than sainfoin under irrigation but in rainfed conditions alfalfa and sainfoin yields were the same. The two cutting frequencies established to benefit either alfalfa or sainfoin, did not show any significantly greater yields under irrigation although it did in rainfed conditions where the delay in cutting afforded a greater yield of dry matter (P<0.01).

When alfalfa and sainfoin were sown in a mixture, the mixture yield was not significantly different to that of the pure stands of alfalfa, both under irrigation and in rainfed conditions. The percentage participation of each species in the mixture varied substantially. Under irrigation alfalfa accounted for 89% of the yield since after the first year sainfoin disappeared from the mixture. This would explain why the forage CP content was closer to that of alfalfa than sainfoin. In rainfed conditions, the DM yield participation of sainfoin in the mixture was 40% when the cutting frequency was carried out with alfalfa in full bloom, this being significantly greater (P<0.01) compared to its 31% participation when cutting took place at early bloom of alfalfa.

These results corroborate the findings of other authors (Monserrat, 1956; Martiniello, 1998; Peel *et al*., 2004; Delgado *et al*., 2008), in so far as alfalfa is more productive under irrigation than sainfoin but has the same yield as sainfoin in rainfed conditions. With regard to the mixture of the two species, sainfoin quickly disappeared under irrigation and this can be attributed mainly to the allelopathic effects of alfalfa on sainfoin and not to the maturity state of the plants at the time of cutting. Although sainfoin did not adapt well to irrigated conditions, its yield was much higher when sown alone compared to when it was sown in a mixture (100% mortality the second year).

However, the percentage of sainfoin plants present in the pure stand by the third year was 19% *vs* 37% of alfalfa plants. The mortality of sainfoin, both in the pure stand and in the mixtures was lower in rainfed conditions. At the end of the third year the persistence of sainfoin in the pure stand was 25% *vs* 62% alfalfa when cutting was carried out at the start of blooming and 17% vs 57% respectively when cutting was carried out at full bloom. The progressive disappearance of sainfoin in the mixture in rainfed conditions, from the first to the third year, could be attributed to the lower persistence of sainfoin rather than to allelopathic effects. Such effects would indeed be more active under irrigation due to the fact that irrigation, which encourages the dispersion of allelopathic chemical components and greater intensity of production, may well accelerate allelopathic actions (de Albuquerque *et al*., 2011).

IV – Conclusions

The interest held by alfalfa under irrigation and alfalfa and sainfoin in rainfed conditions can be confirmed. There is not evidence that frequency cutting impact on disappearance of sainfoin in the mixture, but their disappearance under irrigation could be attributed to allelopathic phenomena. In rainfed conditions there is no evidence of allelopathic phenomena.

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