Soil nutrient status and forage yield at varying distances from trees in four dehesas in Extremadura, Spain

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SUMMARY

The aim of this study was to understand the effect of holm-oak (*Quercus ilex*) on the soil-nutrient concentration and its consequence on the yield of understory forage (*Avena sativa*) in four dehesas of CW-Spain. The soils of the dehesas varied in soil fertility (chromic Luvisols and Achrisols, and eutric Leptosols). Forage dry-matter yields were determined from 1-m^2 sample plots at distances ranging from 2 to 20 m from the tree (9 trees per farm and year). Soil samples (0-30 cm depth) were also collected from the same sampling locations, and were analysed for pH, Electrical Conductivity, organic C, CEC, total-N, available N and base cations. Soil analysis results showed that the most of the values increased in the vicinity of the tree: organic C, total-N, CEC and exchangeable Ca^{2+} and K^{+}. Differences in forage yield were mainly explained by fertilization dosage, light availability (estimated from Montero and Moreno, 2004) and soil CEC. In more fertile soils, forage production was negatively effected by the presence of the trees, as a consequence of light reduction (Competence), while in more oligotrophic soils, forage production was positively affetced by trees (Facilitation).

KEY WORDS: Dehesa, Soil Nutrient Heterogeneity, Forage yield, Competence, Facilitation.

INTRODUCTION

Dehesas are silvopastoral systems of extensive utilization, where autochthonous pastures and periodical crops are combined with scattered trees. Dehesas are the result of simplification in structure and species of Mediterranean oak forests, where tree density is reduced and shrub cover is eliminated. Periodical crop (usually cereal) aims to control shrub encroachment and to obtain a fodder complement for cattle (very useful in both dry and cold seasons).

Research data on the effect of trees on understory forages in the dehesas are required for modeling agroforestry functioning based on tree-crop interactions (HySAFE; Dupraz, 2004), which is expected to be useful to improve the management of these agroforestry systems.

This study was therefore undertaken to gather data on the effect of holm-oak (*Quercus ilex*) on the soil-nutrient status and its consequence on the forage yield in four dehesas of Extremadura, Spain.

MATERIAL AND METHODS

The study was carried out in four holm-oak dehesas of the Cuatro Lugares County, Cáceres (West-Central Spain: 34°4'N, 6°13'W). Climate is Mediterranean, with dry and hot summers and cool, rainy winters, mean annual rainfall of 579 mm, and mean annual temperature 16°C. Soils are mainly chromic Luvisols, in *CL*, and chromic Acrisols, in *SO* and *BA* developed over tertiary sediments (Miocenic feldespatic sands) with abundant quartzite. Both types of soils show a low chemical fertility (Obrador *et al.*, 2004). Eutric Leptosols (in *T*, more fertile soils) have developed on slates from where the sediments have been eroded. Common management practices in dehesa are cattle raising with native pasture and cereal intercrops. Tree density varies from 15 to 50 tree per ha, depending of its main use (lower densities in intercropped areas and higher densities in areas reserved for hunting). Dehesas were dominated by mature trees, ranging from 80-120 years old, and 7-12 m of canopy width.

Forage dry matter yields were estimated from 1-m^2 samples taken at the physiological maturity stage of forage species in four intercropped dehesa farms, with different soil fertility (in decreasing order: *T*, *CL*, *SO* and *BA*; see CEC in Figure 1), and fertilization dosage (from 0 to 250 kg N+P+K ha^{-1}; noted as suscript after farm name). Samples were taken in 2002 and 2003, around nine trees per farm, in two orientations, and four distances (from 2 m, beneath the tree, to 20 m, out of the tree canopy area). Soil samples (composed by five subsamples; 0-30 cm depth) were taken from the same locations in the first days of March. Soil samples were analysed for pH (1:2.5 water), Electrical conductivity, organic C, Cation Exchange Capacity, total N, available P and exchangeable base cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+), following Bigham and Bartels (1996).

RESULTS AND DISCUSSION

Soil analysis results showed that the values of most parameters (CEC, Exchangeable Ca^+ and K^+, Electrical conductivity, organic C and total-N) decreased with the distance away from the tree (see CEC in Figure 1 as example). Similar results have been previously showed in dehesas by Escudero (1985), Puerto *et al*. (1987), Joffre (1987) and Obrador *et al*. (2003). No definite pattern was observed for changes in pH, base saturation, available P and exchangeable Mg^{2+} and Na^+ with distance from trees

Forage productivity showed a very irregular tendency (Figure 1 shows some examples), increasing significantly with distance in T_{200}-2002, BA_{250}-2003 and SO_0-2003. Only in one case, forage yield decreased significantly with distance (SO_{50}-2002). Other cases (CL_{150}-2002, CL_{150}-2003, T_{200}-2003, SO_{50}-2003 and BA_0-2003) did not show any significant tendency. Puerto *et al* (1987) also showed that the pattern of pasture yield around oaks varied with soil quality.

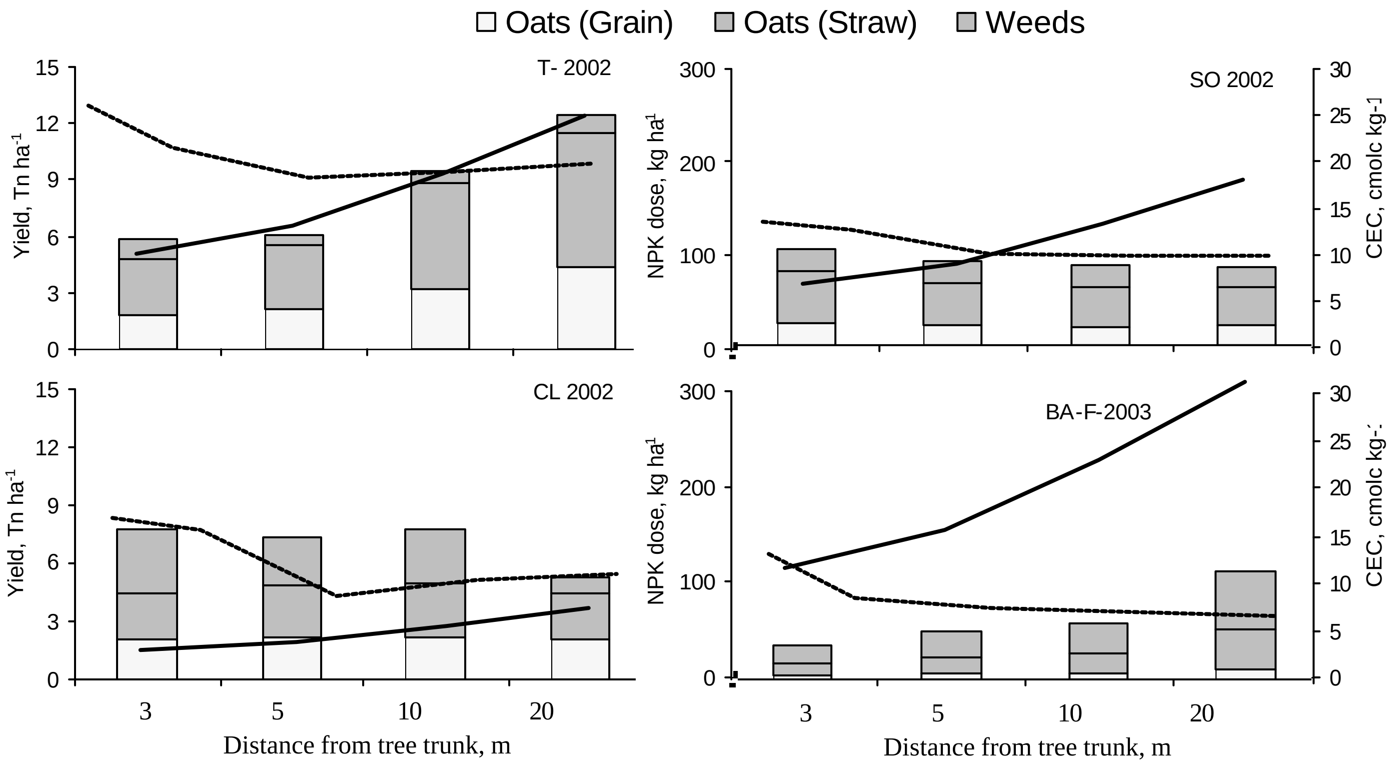

Figure 1 -Mean values of forage yield (including both oats (grain and straw) and weeds) at different distances from the tree stem in four intercropped dehesas, which vary in soil fertility (dashed lines show the mean values of CEC) and in doses of fertilization (50, 150, 200 and 250 Kg ha^{-1} of N+P+K in SO, CL, T and BA, respectively; solid lines show the variation of N+P+K doses with distance).

Multiple regressions have been applied in order to discriminate the role of the different parameters in the forage production (Table 1). The highest part of the variablity was explained by the fertilisation (N+P+K) dosage, which increased with the distance to the tree stem (Figure 1). Light played a minor role (r^2 around 7%). Among the soil parameters, CEC explained around the 16% of the oats yield variability (both straw and grain). Surpringly, SOM and total-N did not contribute significantly to explain the forage variablility.

	Parameter	**Total Biomass**		**Oats Biomass**		**Grain Biomass**	
		r2	**(r)**	**r2**	**(r)**	**r2**	**(r)**
Other	Distance to tree		(+)		(+)		(+)
	Light #	0,066	(+)	0,079	(+)	0,072	(+)
	Fertilization dose	0,358	(+)	0,346	(+)	0,231	(+)
Soil properties	pH-water		(-)	0,049	(-)	0,053	(-)
	Electrical conductivity	0,030	(+)		(+)		(+)
	SOM						
	Total N				(+)		
	Available P	0,032	(+)		(+)		(+)
	CEC		(+)	0,167	(+)	0,160	(+)
	Exchangeable Ca^{2+}				(+)		(+)
	Exchangeable Mg^{2+}		(+)	0,037	(+)	0,032	(+)
	Exchangeable K^+	0,030	(+)		(+)	0,042	(+)
	Exchangeable Na^+	0,167	(-)				(-)
	Base saturation						
	Total Explained Variability	0,74		0,77		0,59	

Table 1 – Percentage of forage yield variability explained by different parameters. Values have been estimated by mutiple regression (r^2 values). In both cases, only significant variables are included. # Data from Montero and Moreno (2004).

CONCLUSION

Soil fertility was significantly improved by the presence of the trees only in the close vicinity of them. However, it seems that the increased fertility did not play any prevailing role on the determination of the forage productivity, except in unfertilized oligrotrophic soils, where forage production was very low, being slightly higher beneath trees than out of the trees.

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