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Assessment of plant covers with native legumes in Mediterranean semi-arid woody crops

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Abstract. The aim of this work is to present the design of handling methods carried out with plant covers over a period of 12 consecutive years in an olive and vineyard grove on the experimental plantation La Higueruela (Toledo, Spain). Starting from the initial working hypotheses, connected with minimising the soil erosion which had been produced by the conventional management of these woody crops for more than 50 years, the benefits of plant biodiversity (weed vegetation) and covers with subterranean clover, have been considered and the question of how to manage permanent covers. Ecological cover use may be systematised under the headings which encompass the main results obtained: (i) environmental services of permanent plant covers; (ii) use of main functional groups of the communities proceeding from the soil seed bank; (iii) sustainable management of N and C in the very olive grove system; and (iv) minimisation of competition for water by paying attention to the evaluation of autochthonous leguminous crops adapted to the constant fluctuations of a Mediterranean climate. Although previous works have set out results from this research, we now offer an evaluation from what might be regarded as the perspective of ecological engineering.

Keywords. Autochthonous leguminous – Environmental services – Sustainable management – Water competition – Ecological agriculture.

Évaluation de couvertures de légumineuses autochtones dans des cultures ligneuses méditerranéennes semi-arides

Résumé. *L'objectif de ce travail est de présenter la conception de méthodes de gestion réalisées avec la couverture végétale pendant une période de douze années consécutives dans une oliveraie et un vignoble sur la plantation expérimentale de La Higueruela (Tolède, Espagne). À partir de l'hypothèse de travail initial, liée à la minimisation de l'érosion des sols causée par la gestion traditionnelle de ces cultures ligneuses pendant plus de cinquante ans, les profils de la biodiversité végétale (la végétation adventice) et de la couverture de trèfle souterrain ont été envisagés et la question de savoir comment gérer la couverture végétale permanente. L'utilisation de la couverture écologique peut être systématisée dans les rubriques comprenant les résultats principaux obtenus : (i) les services environnementaux des couvertures permanentes ; (ii) l'utilisation des principaux groupes fonctionnels de communautés en provenance du stock semencier du sol ; (iii) la gestion durable du N et C dans chaque système d'oliveraie ; et (iv) la minimisation de la concurrence pour l'eau, en faisant attention à l'évaluation des cultures de légumineuses autochtones adaptées aux fluctuations constantes du climat méditerranéen. Bien que les œuvres précédentes aient décrit les résultats de cette recherche, nous offrons maintenant une évaluation de ce qui pourrait être considéré comme un point de vue de l'ingénierie écologique.*

Mots-clés. *Légumineuses autochtones – Services environnementaux – Gestion durable – Concurrence pour l'eau – Agriculture biologique*.

I – Introduction: Research approach

This work highlights the most important aspects of the different strategies, carried out during 12-year, for the use of legumes covers in rainfed olive groves and vineyards, which had been

managed under bare soil for more than 40 years and whose soils had erosion problems and very low levels of soil organic matter (SOM).

Based on the concepts, principles and ecological processes, essential for the development of rainfed organic agriculture we applied a wide range of methodologies, i.e. ecopedological relationships, ecophysiology of mineral nutrition, legumes autoecology and agroecosystems management (Hernández *et al.*, 1997).

The aim of this work is to evaluate the different management of cover crops use of wild authochtonous and cultivated legumes as cover crops dealing with ecological criteria: (i) environmental services of the cover crops; (ii) using functional groups of communities from the soil seed bank; (iii) sustainable management of C and N fluxes; and (iv) minimization of water competition by means of adapted ecotypes which allows to reach a sustainable development.

II – Materials and methods

The experiment was performed at the experimental farm "La Higueruela" (Sta. Olalla, Toledo, Spain), belonging to CSIC. The area has a semiarid climate, with irregular, and frequently torrential rains, which favour the runoff and loss of soil (Hernández *et al.*, 1997). The experimental design and the soil analysis have been described in Hernández *et al*. (2005).

III – Results and discussion

Here we show the main results obtained for the different management strategies of the cover crops during 12 years. Firstly, the methodological steps are described, and then, the actions and results obtain in each step.

1. 1st step: Evaluation of the ecological behaviour of different covers

Different ecological criteria are applied in order to evaluate permanent herbaceous covers in olive groves and vineyards in a Mediterranean semiarid environment. The ecological principles of rainfed organic agriculture are based on nutrients conservation, by means of the N and OM inputs provided by legumes covers, and the minimization of water competition. The evaluation requires: (i) studying the behaviour of different legumes with different phenology and, if possible, with self-reseeding capability; (ii) evaluating the soil seedbank response in plots with weeds; and (iii) designing management strategies for this permanent herbaceous covers. The results of the seasonal monitoring of the species composition and of the cover percentage, the study of moisture in the soil profile (0-60 cm) in critical periods of water availability for both crops and the annual yield.

2. 2nd step: Identify the critical points in the woody crops

In the beginning of the project we detected high levels of erosion, high competition between the herbaceous covers and the woody crops, and very low levels of organic matter in the soil. The first aspect led us to provide hay from the native herbaceous covers, rich in legumes (see Table 1), in the olive grove to the vineyard, in order to enrich the covers in the latter. Additionally, in order to increase the low levels of SOM chipped branches from olives and vines were spread as mulch, and also, legumes would provide nitrogen trough the symbiotic fixation (Tables 3 and 4).

3. 3rd step: Selection of diagnosis criteria and indicators

(i) Plant cover, as an estimation of the "lack of soil erosion"; (ii) moisture in different soil levels

(0-20, 20-40 and 40-60 cm), for evaluating the eventual water competition with the cover crops; and (iii) analysis of the soil parameters related to the objectives.

Table 1. Species richness (mean number per plot) in olive groves with native herbaceous cover during 10 years. The symbol + indicates only presence

Legumes	1º	2º	3º	4º	5º	6º	7º	8º	9º	10º
Species richness/year	7	8	8	9	10	10	12	10	8	10
Ornithopus compressus	+	6	16	61	32	55	35	43	12	25
Biserrula pelecinus	+	4	14	32	10	37	23	22	9	18
Trifolium arvense	+	5	4	5	2	3	2	1	1	4
Lupinus angustifolium	+	1	1	3	+	2	2	1	+	1
Otrer legumes	2	7	16	10	3	9	13	5	2	3

Table 2. Plant cover (%) in the 2nd and 6th years of study in the olive groves and vineyard

Type of cover	Olive grove		Vineyard	
	2nd year	6th year	2nd year	6th year
Subterranean clover	51	84	86	86
Native cover	69	90	48	85

Table 3. Mean values of nitrates in soil (ppm) ± standard error in the olive grove

Type of cover	2nd year	6th year
Native cover	18.5 ± 11.3	27.9 ± 4.7
Subterranean clover	9.2 ± 1.3	20.0 ± 4.2
Vetch	9.7 ± 4.4	21.9 ± 2.7

Table 4. Mean values of easily mineralizable soil organic matter (EMSOM, %) and soil organic matter in the clay-humic complex (SOMCHC, %) ± standard error for different covers after 5 years of applying the same treatment in the olive grove

Covers	EMSOM	SOMCHC
Native herbaceous cover	0.46 ± 0.15	0.84 ± 0.36
Subterraneum clover	0.35 ± 0.03	0.82 ± 0.18
Vetch	0.45 ± 0.30	0.54 ± 0.03

4. 4th step: Samplings and indicators monitoring

Plant cover samplings are carried out in spring and autumn, as they are the most critical moments for erosion in bare soils, under Mediterranean semiarid climate. Additionally, in these seasons most of spontaneous plants in the area are at the end of their phenological phase. Soil

moisture was monthly monitored, initially with gravimetrical techniques and, subsequently, with Dataloggers EM5 equipments and moisture probes (ECH_2O of Decagon).

5. 5th step: Integration of the results dealing with ecological criteria

We selected native covers and early-middle ecotypes of *T. subterraneum*, because of its creeping shape, fast growing, superficial root development, rainfalls adaptation, N fixation and self-reseeding capabililty, low competion with the woody crops, which have resulted very efficient for our purposes. A mixture of the Nungarin, Daliak and Esperance subterranean clover cultivars were sown in autumn, in the first year of the experiment. Then, they were selfreseeded during the following years. Additionally, vetches (*Vicia sativa* L.) were used as cover crops in the olive grove. The results related to wild autochthonous legumes from the seed bank of the olive grove (Table 1) led us to increase the quantities of legumes in the vineyard by means of mowing the vegetation in the olive grove and spreading it in the vineyard plots with native cover. In the latter, subterranean clover invaded the native cover plots and erosion was diminished (Tables 5 and 6), but also, grape yield diminished with respect to plots under traditional tillage. For this reason, we implemented a new strategy of cover management: cover rotation in order to protect the soil in the vineyard without reducing the yield (Table 6).

Table 5. Plant cover percentage in the vineyard soil during several years

Type of cover	2º	3º	4º	5º	6º	7º	8º	12º
Subterranean clover	86	95	95	91	85	86	52	86
Native cover	48	49	53	87	86	90	31	81

Table 6. Plant cover (%) provided by legume species in native cover plots (NC) and subterranean clover plots (SC) in the olive grove and the vineyard. (+) indicates presence

Species	Olive grove				Vineyard			
	1st year		10th year		1st year		10th year	
	NC	SC	NC	SC	NC	SC	NC	SC
Ornithopus compressus	+	-	45	7	-	-	17.3	11.3
Biserrula pelecinus	+	-	25	6	-	-	10	2.7
Lupinus angustifolium	-	-	0.6	+	0.8	-	+	-
Trifolium arvense	+	-	1	0.5	-	-	8.3	1.7
Trifolium subterraneum	-	14	1	30	-	60	10.7	36.7
Other legumes	2	2	2	2	<1	<1	2	2
Diversity (no. sp)	73	51	58	46	73	44	69	53

The main environmental services of the herbaceous legume covers in Mediterranean semiarid agroecosystems are soil protection and N fixation. However, it is indispensable to know the proper cover management for each type of soil according to the climatic conditions along a period not shorter than 10 years if we want to provide guidelines for the new management of a traditional farm. Therefore, the knowledge of the autoecological behaviour of the species after the change of use is crucial. Additionally, after the 4th year after the change of use, high diversity and plant cover are achieved, and this allows mowing and exporting the hay to other places. This practice reduces weed competence, but also, impedes the enrichment of the seed bank. In the vineyard we observed that subterranean clover were the best competitors with the weedy species.

IV – Conclusions

The assays on herbaceous covers in an olive grove and a vineyard, belonging to the same farm in a Mediterranean environment, allows to increase biodiversity, preserve soils, and detect which species are adapted to the pedoclimatic conditions. The mulch of chipped branches was not a successful management, as it does not allow seed germination of herbaceous species and it provides low quantities of OM to the soil due to the low rainfalls registered. Additionally, the management of the covers must be carried out according to ecological criteria: autoecology of herbaceous species, rotations after the stabilization of the ecological succession, flux coupling (nutrients and seeds) between both systems, etc.

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