Soil protection and carbon sequestration through seeded groundcovers, spontaneous vegetation and pruning remains mulch in olive orchard

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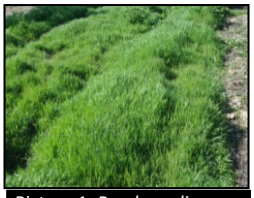
Introduction

Olive orchard is well-adapted to Mediterranean conditions so this crop has economic, social and environmental importance in this area. Woody crops are considered lands with scarce soil protection as canopies provide less than 30% of soil cover and, in many cases, olive trees are placed in marginal areas with steep slope what eases erosion processes. In addition, some agricultural practices like intense tillage or bare soil favour soil loss. Groundcovers have been proven to be efficient controlling erosion in olive orchard. Furthermore, they have the ability to fix atmospheric carbon and improve soil organic carbon (SOC). Different types of groundcovers can be used by farmers. GC can be composed by seeded species. Among them, Gramineae, Leguminosae and Cruciferae should be highlight as the main families.

The aim of this research was to assess soil protection capacity and the carbon sequestration potential of different GC comparing the spontaneous vegetation in each area with 3 seeded species from the main families and pruning remains used as mulch.

Materials & Methods

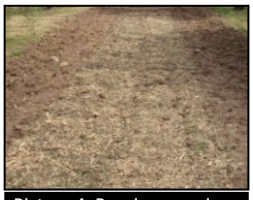
A four-season study with four experimental fields (**Table 1**) was performed to assess the protection provided and the carbon sequestration potential of seeded species from different families of plants and the spontaneous vegetation of the area. The seeded groundcovers were a grass (*Brachypodium distachyon*) (**Picture 1**), a crucifer (*Sinapis alba*) (**Picture 2**) and a legume, hairy vetch (*Vicia villosa*) (**Picture 3**), each of them was sown in a different field and compared with the specific natural flora. In the fourth field, mulching system with scattered pruning remains from olive trees (**Picture 4**) were tested and compared to the natural vegetation of the area. The dose of pruning remains was established from the average of pruning weight obtained per tree, the distance between two trees and a strip of 2 m (chopping machine width). Soil coverage during the decomposition period and carbon fixation in soil were measured in all types of groundcover considered.



Picture 1. *Brachypodium distachyon* (Field 1)

Picture 2. *Sinapis alba* (Field 2)

Picture 3. *Vicia villosa* (Field 3)



Picture 4. Pruning remains mulch (Field 4)

Table 1. Soil properties of the experimental fields. (OM: organic matter; CEC: Cation exchange capacity; BD: bulk density))

Field	Depth (cm)	OM (%)	CEC (mol_c/kg)	$CaCO_3$ (%)	BD (Mg/m^3)	Sand (%)	Silt (%)	Clay (%)	Textural class
1	0-20	0.87	0.23	29.2	1.32	7.9	41.4	50.7	Silty clay
	20-40	0.66	0.22	31.8	1.43	8.4	41.7	49.9	Silty clay
	40-60	0.58	0.22	33.1	1.44	8.8	41.8	49.4	Silty clay
2	0-20	1.12	0.34	1.5	1.42	35.4	25.4	39.2	Clayey loam
	20-40	1.10	0.39	1.5	1.47	31.7	24.8	43.5	Clayey
	40-60	0.75	0.39	2.6	1.47	29.3	23.0	47.6	Clayey
3	0-20	2.18	0.14	15.7	1.30	57.4	26.7	15.8	Sandy loam
	20-40	2.07	0.13	15.4	1.40	56.2	28.2	15.5	Sandy loam
	40-60	1.37	0.13	20.9	1.41	62.6	25.3	12.0	Sandy loam
4	0-20	1.96	0.20	16.4	1.48	42.5	39.9	17.6	Loamy
	20-40	1.29	0.19	20.4	1.49	44.3	37.6	18.1	Loamy
	40-60	1.03	0.17	20.9	1.50	45.1	38.6	16.3	Loamy

Carbon sequestration

Regarding carbon sequestration (**Fig. 1**), pruning remains reached the greatest annual rate of 3.5 Mg C ha^{-1}. However, it covered lower (2 m) strip surface than living groundcovers (3.5-4 m). Brachypodium increased SOC 1.9 Mg C ha^{-1} annually in the field with the highest clay content. Sinapis obtained an average fixation of 1.8 Mg C ha^{-1} per season and vetch improved SOC 1.1 Mg C ha^{-1} y^{-1}. Instead, spontaneous vegetation provided lower sequestration rate in the four fields, the values ranged between -0.2 and 1.7 Mg C ha^{-1} y^{-1} (**Table 3**). Among the experimental fields, those where the soil clay content was higher and initial SOC was lower gave better increments.

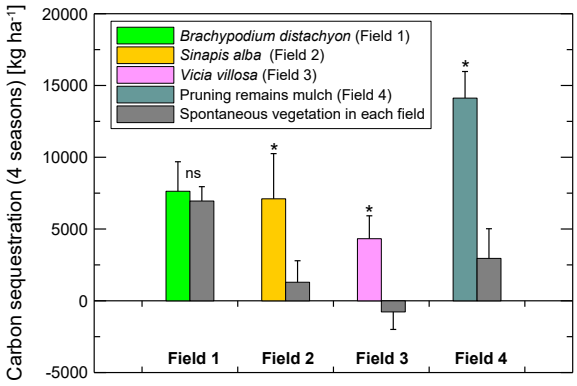


Figure 1. C sequestration (kg/ha) obtained through groundcovers at 0-20 cm depth during the 4-season study period in each field (*significant differences; ns: non-significant differences with spontaneous vegetation of the same field according to LSD test at $p \leq 0.05$)

Results & Discussion

Soil coverage

The seeded groundcovers showed higher soil cover than spontaneous vegetation throughout the study period. Brachypodium was the species that provided a higher and long-lasting protection level with values over 75% at the end of the decomposition period of the four seasons. In all fields, the seeded specie was more protecting than spontaneous. The pruning remains mulch maintained the soil cover quite high until the fourth season where the value was lower of 30% at the end of the season since there was not a new application of pruning remains during four years (**Table 2**).

Table 2. Soil cover provided by the groundcovers residues at the end of the decomposition season. (BRA: *Brachypodium distachyon*; SIN: *Sinapis alba*; VIC: *Vicia villosa*; PRM: Pruning remains mulch; SV_: Spontaneous vegetation in each field. *significant differences; ns: non-significant differences with SV according to LSD test at $p \leq 0.05$)

Season	Field 1			Field 2			Field 3			Field 4		
	BRA		SV1	SIN		SV2	VIC		SV3	PRM		SV4
1	84.1	*	36.8	34.5	ns	29.0	30.4	ns	25.0	85.3	*	49.9
2	99.3	*	78.1	41.3	ns	39.0	58.0	*	28.0	62.5	*	39.2
3	79.0	ns	66.0	48.3	ns	41.5	62.8	*	22.0	34.8	*	60.3
4	90.0	*	58.9	51.8	ns	39.8	44.2	ns	42.2	22.3	*	72.6

Table 3. Annual C sequestration rate (Mg/ha/year) and 4perMille rate (annual rate/baseline C stock×1000). (BRA: *Brachypodium distachyon*; SIN: *Sinapis alba*; VIC: *Vicia villosa*; PRM: Pruning remains mulch; SV_: Spontaneous vegetation in each field))

	Field 1		Field 2		Field 3		Field 4	
	BRA	SV1	SIN	SV2	VIC	SV3	PRM	SV4
Annual C sequest. rate	1.91	1.74	1.78	0.32	1.08	-0.19	3.53	0.74
4perMille rate	146.4	129.1	77.1	14.0	47.4	-8.4	102.8	21.5

Conclusions

The use of groundcovers in olive orchard is highly recommendable because they can protect the soil and mitigate climate change through SOC sequestration. The treatments where farmers had a role, such as seeded groundcovers and pruning remains, worked better than spontaneous vegetation, which is the most used groundcover.