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Effect of soil management techniques on performance of different grain legumes in a Mediterranean environment

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SUMMARY – The research was carried out during 2000-2002 in a typical semi-arid Mediterranean environment to evaluate the effects of three different soil management practices (no tillage NT, mulch tillage MT and conventional tillage CT) on faba bean, chickpea, pea and lentil crops. A split-plot design with three replications was used. Biometrical and phenological characteristics, grain yield components and nitrogen grain content were recorded. Two-year mean grain yield was significantly greater under NT than CT (+21.5%), but the differences among tillage regimes were markedly affected by species and climatic conditions; the highest yield benefits of NT were in pea and chickpea in the drier year. No significant differences between MT and CT were recorded. Moreover, N grain was not affected by tillage regimes.

Key words: Conventional, mulch and no tillage, grain legumes, grain yield, nitrogen content.

RÉSUMÉ – *"Effet des techniques de gestion du sol sur les performances de différentes légumineuses dans un environnement méditerranéen". La recherche a été réalisée en 2000-2002 dans un milieu semi-aride typique méditerranéen pour évaluer les effets de trois différentes techniques de travail du sol (NT : sans labour ; MT : mulch tillage ; CT : labourage classique) pour les cultures de fève, pois chiche, pois et lentille. On a adopté un schéma expérimental split-plot avec trois répétitions. On a relevé les caractéristiques biométriques et phénologiques des cultures, les composantes de la production de grain et de son contenu en azote. Le rendement moyen pendant les deux années a été significativement supérieur en NT par rapport à CT (+21,5%), mais les différences entre les régimes de labourage ont été nettement affectées par l'espèce et les conditions climatiques ; les avantages de rendement les plus élevés du NT étaient sur le pois et sur le pois chiche dans l'année plus sèche. Aucune différence significative entre la MT et CT n'a été enregistrée. Enfin, le contenu de N dans les grains n'était pas affecté par le régime de labourage.*

Mots-clés : *Labourage classique, mulch tillage et sans labour, légumineuses à grain, rendement en grain, contenu d'azote.*

Introduction

In most countries of the Mediterranean basin, pulses acreage has strongly decreased over the last decades; however, grain legumes can still play a key role in Mediterranean cropping systems because they enhance the productivity and potential sustainability of farming systems providing biological fixed nitrogen and helping to control pests, diseases and weeds (Howienson *et al*., 2000). However, to remain profitable and environmentally sustainable, these crops have to be managed in systems that reduce erosion risks and preserve soil quality.

Farmer's interest in conservation tillage techniques is recently increased due to many advantages with respect to conventional tillage (improvement of soil water retention and organic matter content, erosion control, labour costs and time savings, etc.) (Martens, 2000). Several studies have already showed how the adoption of conservation tillage is considered as one of the more effective alternative options for cereal crop systems (Bonari *et al.*, 1994; Arshad and Gill, 1997), but little information is available on the influence of conservation tillage on the performance of grain legumes.

The objective of this study was to evaluate, in a typical rainfed Mediterranean environment such as the inner area of Sicily, the effect of different tillage systems (conventional, mulch and no tillage) on productive and qualitative characters of faba bean, chickpea, lentil and pea.

Materials and methods

The research was conducted during the 2000-01 and 2001-02 seasons at Pietranera Farm (37°30'N; 13°31'E; 178 m a.s.l.) on a deep, clayey, calcareous, well structured soil, classified as a *Vertic haploxerepts* (USDA-NRCS, 1999) and with wheat as previous crop. Soil physical and chemical properties of the surface 0.40 m were as follows: 49.8% clay; 23.2% silt; 27.0% fine sand; 8.0 pH (in water); 20.3 g/kg organic matter (Blake-Walkley method); 1.24 g/kg total N (Kjeldahl method); 77 mg/kg assimilable P_2O_5 (Olsen method); 230 mg/kg exchangeable K_2O (Int. method).

The experiment was designed as a randomized complete block with a split-plot arrangement and three blocks. Main plots were soil tillage techniques: no-tillage (NT), mulch tillage (MT) and conventional tillage (CT); sub-plots were legume species: faba bean (*Vicia faba* L. var *minor*), chickpea (*Cicer arietinum* L.), pea (*Pisum sativum* L.) and lentil (*Lens culinaris* M.). The area of sub-plot was 90 m^2 (6 x 15 m).

NT plots were seeded directly with a no-till seed drill with residues of the previous crop left on the soil surface; weeds were controlled with glyphosate at the rate of 0.8 l a.i./ha, prior to planting. In MT plots the soil was disturbed, prior to seeding, with a minimal mechanical seedbed preparation using field cultivators; weed control was accomplished with cultivation. The CT treatment involved mouldboard ploughing (25-30 cm depth) in summer time, followed by autumn secondary tillage operations with a field cultivator in order to prepare a proper seedbed and to control weeds. At all plots phosphorous fertiliser was applied before sowing at a rate of 92 kg P_2O_5/ha.

In each year all species were sown in December at a depth of 3-5 cm. Pea (cv Baccarà), chickpea (accession PA3), faba bean (cv Sikelia) and lentil (ec. Villalba) were sown at 80, 60, 50, 150 viable seeds/m^2 respectively; inter-row spacing was 0.32 m for chickpea and faba bean and 0.16 m for lentil and pea. Before crop emergence, weeds were controlled with Imazetapyr + Pendimethalin, using different rates for each crop.

Dates of the main phenological stages were recorded. At harvest, in three sample areas of 5.76 m^2 for each sub-plot, total aboveground biomass, number of plants and grain yield were recorded; furthermore biometrical traits and grain yield components were measured. In 2001-2002 legume grains were ground to pass a 1 mm mesh and sub-samples were analysed for nitrogen concentration using the Kjeldahl method.

Statistical analysis was performed using a split-plot experimental design and a General Linear Model; crop data for each year were analysed separately and where possible on the basis of homogeneity of variance, combined over years with year as random variable. LSDs for main effect and interaction comparisons were calculated using the appropriate standard error terms (Gomez and Gomez, 1984).

Results and discussion

The two cropping seasons were different according to the rainfall (599 and 309 mm respectively in Sept.-June 2000-01 and 2001-02). In 2000-01, winter rainfall accounted for more than 70% of the annual total and spring was particularly dry (65 mm); in 2001-02 rainfall was poor but distribution was generally favourable for crop growth (Fig. 1).

In Table 1 the results of the analysis of variance for productive data are reported. Soil tillage techniques markedly influenced grain yield. On average, no tillage, compared to conventional tillage, allowed a 21% grain yield increase (Table 2); however the yield benefits were different for each crop (interaction C x T significant; $P < 0.01$) and in the two trial years (interaction Y x T significant; $P < 0.05$). On the two-year period average, grain yield of pea and chickpea were significantly greater under no tillage than conventional tillage (+32% and +19%, respectively) whereas no significant differences were found for faba bean and lentil (+8% and +17%, respectively). Moreover, the no tillage gave the highest advantages, compared to conventional tillage, in 2000-01 (+45%) that, as previously mentioned, was a dry cropping season. These results agree with the findings of Giambalvo *et al*. (1999) who reported that in dry conditions no tillage technique is most effective in enhancing wheat yields.

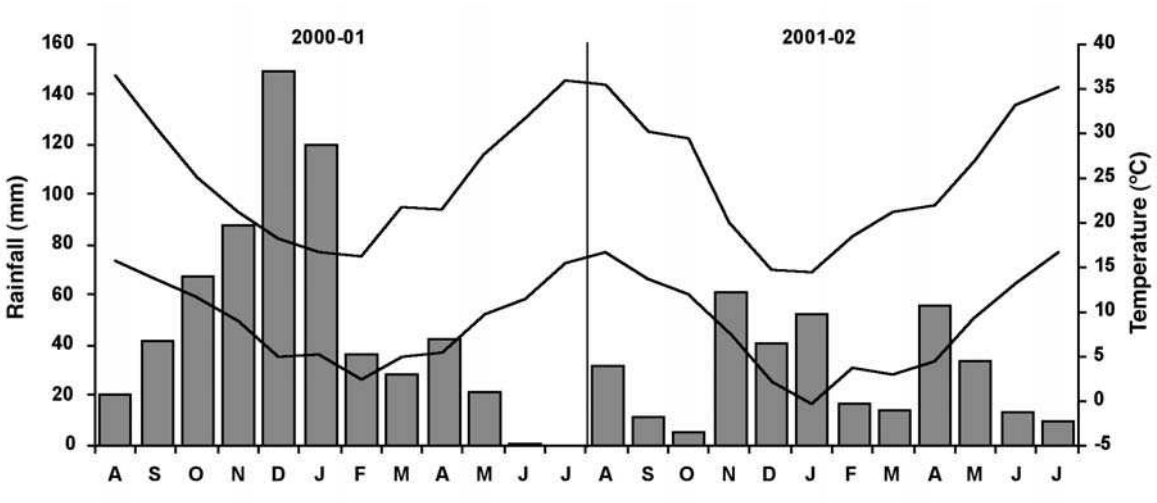

Fig. 1. Monthly total rainfall and mean values of minimum and maximum temperatures during the trial period at the experimental site.

Table 1. Analysis of variance for the crop production data

Source	df	Grain yield	Above-ground biomass	Plants/ m^2	Pods/ plant	Pods/ m^2	Seeds/ pod	1000 seed weight
Year (Y)	1	*	*	**	NS	**	NS	**
Error A (Y x Block)	2	0.445	3.878	85.4	4.79	28302	0.009	1.11
Tillage (T)	2	***	**	NS	*	*	NS	*
Y x T	2	*	NS	*	**	NS	NS	**
Error B [Block x T (Y)]	8	0.059	0.446	118.2	1.22	17438	0.026	118.7
Crop (C)	3	***	***	***	***	***	***	***
Y x C	3	***	***	*	***	***	NS	NS
T x C	6	**	*	NS	NS	*	NS	NS
Y x T x C	6	*	*	NS	*	NS	NS	NS
Residual error	36	0.079	0.218	155.9	1.67	14430	0.036	264.7

*,**,***Indicate the effect is significant at P ≤ 0.05, 0.01 and 0.001 respectively; NS = not significant.

Furthermore, results showed that no tillage, compared with conventional tillage, allowed the highest yield in both years for pea and only in the second year for chickpea; in both years, the differences were not significant between the two techniques for faba bean and lentil crops.

Generally, grain production did not have appreciable variations between conventional and mulch tillage. The different soil tillage techniques did not significantly influence either the dates of the main phenological stages or the biometrical traits observed.

On the whole, the responses observed for aboveground biomass production were similar to grain yield (Table 2). On average, the increases of grain yield with no tillage was associated to a significant higher number of pods/m^2 and 1000 seeds weight than with the conventional tillage.

The soil tillage techniques did not significantly affect protein seed content, even if a slight decrease was observed in chickpea under NT compared to CT (25.9% vs 27.4%, respectively). The highest protein value was observed, on average, in faba bean (29.2%) and the lowest in pea (25.7%).

Table 2. Grain yield and aboveground biomass produced by grain legumes in the two trial years under the CT, MT and NT†

	Grain yield (kg/ha)				Aboveground biomass (kg/ha)			
	CT	MT	NT	Mean	CT	MT	NT	Mean
Chickpea								
2001	2894a	2810a	2949a	2884A	8507a	8442a	8626a	8525A
2002	1423b	1916a	2175a	1838B	3414b	4369a	4659a	4147B
Mean	2158b	2363ab	2562a		5961b	6405a	6642a	
Faba bean								
2001	3708a	3216b	4010a	3644A	8257ab	7595b	8908a	8254A
2002	1651a	1886a	1969a	1835B	3328a	3501a	3762a	3530B
Mean	2679ab	2551b	2989a		5793ab	5548b	6335a	
Lentil								
2001	1372a	1370a	1471a	1404A	5968b	5979b	7205a	6384A
2002	662a	601a	914a	725B	3588b	4051ab	4745a	4128B
Mean	1017a	985a	1192a		4778b	5015b	5975a	
Pea								
2001	4200b	4148b	4776a	4374A	7010b	7259b	8040a	7436A
2002	3179b	3612b	4939a	3910B	6105b	6221b	8478a	6935B
Mean	3689b	3880b	4857a		6557b	6740b	8259a	
Averaged across years and crops								
Mean	2386b	2444b	2900a		5772b	5927b	6803a	

†Means followed by different letters differ significantly based on the LSD at P ≤ 0.05; lower-case letters refer to the tillage effect in a given row within the grain yield or above biomass sections; capital letters refer to the year effect in a column within the chickpea, faba bean, lentil or pea sections.

Conclusions

The study showed that in a Mediterranean semi-arid rainfed environment, no tillage technique could represent a suitable alternative to conventional tillage in order to improve yield performance of grain legumes. The research confirmed that no tillage is most effective in enhancing yield in dry years. The significant tillage x crop interaction for grain yield indicated that the crops responded differently to tillage techniques. However, the marked yield benefits found with no tillage for pea could not be explained simply by moisture availability, since the first was very wet and the second dry; a more complex mechanism must therefore have been responsible and should be the subject of further research.

No differences in grain yield were found between conventional and mulch tillage; such a result is nevertheless of interest because MT can offer extra benefits such as reduction of runoff, erosion, inputs and costs.

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