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Green manuring as sustainable management for southern Italy extensive cultivated areas

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SUMMARY – In the extensively-managed agricultural areas of Sicily, rainfall is often so limited that economically effective annual productions are not feasible. Bare fallow, the most extreme dry-farming technique, seems to be, under such conditions, the only suitable strategy. The introduction in these cropping systems of an annual legume to put early into the soil, as an alternative to bare fallow, may represent a technique able not only to prevent soil erosion, but also to improve the low soil organic matter reserves, with a direct benefit on the following yields and on the whole environment. The trial was aimed to verify the bioagronomical and qualitative behaviour of durum wheat managed under different cropping systems. Results, heavily influenced by very low rainfall (320 mm), stressed the extraordinary productive response of durum wheat cultivated after the green manure legume.

Key words: Green manure, durum wheat, cropping system, sustainable agriculture.

RÉSUMÉ – *"L'engrais vert pour la gestion durable dans les zones de cultures extensives du Sud de l'Italie". En Sicile dans les terrains destinés à la culture extensive, la pluviosité est tellement limitée que les productions annuelles économiquement rentables ne sont pas possibles. La jachère nue, la plus extrême des techniques d'aridoculture semble être, dans ces conditions-là, la seule praticable. L'introduction, dans ce système cultural, d'une légumineuse annuelle à incorporer d'avance dans le sol, en alternance avec la jachère nue, peut représenter une technique capable de prévenir l'érosion du sol, mais aussi d'augmenter le bas niveau de substances organiques du sol avec un avantage direct pour les productions successives et pour tout l'habitat. L'expérience devait vérifier le comportement bio-agronomique et qualitatif du blé dur soumis à différents systèmes de cultures.*

Mots-clés : *Engrais vert, blé dur, rotation culturale, agriculture durable.*

Introduction

In the middle-east Sicilian extensive agricultural areas, annual rainfall is so limited (<350 mm/year) that it does not permit annual remunerative agricultural practices. In such conditions, bare fallow (about 100,000 ha in Sicily), an extreme rainfed agriculture technique is often utilized (Istat, 2003).

Continuous bare fallow techniques, although they allow higher water availability for the cash crop as well as yield suitability and stability every two years, cause a fast soil organic matter content reduction which has negative repercussions on some chemical and physical soil characteristics (aggregate stability, soil water content, microbiological activity, etc.) and the bare soil is subject to erosion processes due to rainfall determining a general depletion of soil fertility.

Introduction of legumes in the Sicilian cropping systems, to avoid traditional bare fallow and early leguminous green manuring to limit an excessive water consumption, could be an innovative management technique able not only to preserve soil from erosion risk but also to improve soil organic matter reservoirs determining a direct benefit on the following crops and on the environment.

Leguminous crops, can also improve, through their biological nitrogen fixation ability, great low cost atmospheric nitrogen quantities, probably used by the following crops in the cropping system.

Apart from the positive agronomic effects, these techniques seem to be suitable in relation to the new European agriculture policies (European Commission, 2003), aimed at an increase in the sustainability of the cropping systems, a reduction in external energetic inputs and protection of the environment (cross-compliance).

The aim of this paper is to compare the effects of five different cropping systems on durum wheat and verify the agronomic suitability of leguminous green manure in comparison to the traditional techniques.

Materials and methods

Trial site

The trial was carried out during 2001-02 on the Experimental Farm Sparacia (AG, 37°37'N, 13°42'E) of the Department A.C.E.P. of Palermo University, site representative for durum wheat cultivations in the hilly Sicilian inland, characterized by a sub-arid climate with a yearly rainfall mean of about 500 mm concentrated in the fall-winter period, with minimum and maximum temperature means respectively of 9 and 21 °C. The trial was carried out on a Eutric Vertisol representative of the pedotype of the area, according to WRB (FAO-ISRIC-ISSS, 1998).

Management and layout of the field trials

The trial consisted of a randomized block design with three replications in which nine treatments were compared, as reported in Table 1.

Table 1. Compared cropping systems

Cropping system	N rate	Acronym
Durum wheat – bare fallow	0.80	W-F/0, W-F/80
Durum wheat – grain vetch	0.80	$W\text{-}V_g/0$, $W\text{-}V_g/80$
Durum wheat – hay vetch	0.80	$W\text{-}V_h/0$, $W\text{-}V_h/80$
Durum wheat – green manure vetch	0.80	$W\text{-}V_{gm}/0$, $W\text{-}V_{gm}/80$
Durum wheat – durum wheat	80	W-W/80

The first four cropping systems in interaction with two nitrogen levels were tested (N0, N80 = 80 kg/ha); instead on durum wheat monocropping (control), only one nitrogen level (N80) was used. The durum wheat (cv Valbelice, a very rustic variety) sowing took place on 01/04/02 using 350 germinable seeds/m^2 in rows 20 cm apart. Vetch, was sown on 15/11/00 using 200 seeds/m^2.

During the first ten days of April, green manured vetch ($W\text{-}V_{gm}$) was incorporated in the soil at the flowering stage [about 15 t/ha fresh weight (d.m. 18%) and a nitrogen content of 1.6% d.m.]. The crop was fertilized, in all its treatments, with 92 kg/ha of phosphoric anhydride.

Grain yield, yield components and qualitative parameters

At harvest the plants were measured for the following characteristics: plant height (cm), spike numbers/m^2 (n), dry seed production (t/ha); on the grain: shrivelled kernels (%), thousand kernel weight (g), test weight (kg/hl), grain moisture (%).

The following analyses were carried out on whole flour: flour moisture (%), dry matter (%), total nitrogen (N% x 5.7 = proteins d.m. %), dry gluten (d.m. %), gluten index (%), sedimentation index (ml) and ash (d.m. %).

Statistical analysis

Analysis of variance was performed on all bioagronomic and qualitative data. The differences between the means were estimated with a Tukey test (α = 0.01).

To compare single effects of the four different cropping systems, performance in comparison to the test cropping system (W-W/80), four groups "over nitrogen" were arranged (Gr. W-F, Gr. W-V_{gm}, Gr. W-V_g, Gr. W-V_h) to carry out contrasts (Steel and Torrie, 1980).

Percentages, to satisfy variance homogeneity conditions, were transformed through the square root method for percentage values and through arcsine transformation for protein. The coefficient of variation (cv), calculated as percent ratio between the standard deviation and the grand mean (Error $MS^{1/2}$/Grand mean x 100), was used to evaluate the experimental result reliability.

Growing conditions during trial period

In 2001-02 the rainfall was rather low (320 mm) and had an irregular distribution, and did not adequately satisfy the crop water requirements. In particular, two water shortage periods occur. The first in the September-October period (-24 and -60 mm respectively compared to the thirty-year means) did not allow the correct preparation of the sowing bed and above all did not allow an adequate soil water storage to be later used during the crop vegetative-productive cycle. The second during the 2^{nd} ten days of February – 2^{nd} ten days of March (overall -50 mm) caused a direct water stress on the young seedlings negatively conditioning their future development. A late rainfall, of about 40 mm, occurs during the second ten days of May. The temperatures were very similar to the thirty-year means.

Results and discussion

Low rainfall strongly determined agronomic performances of the different tested rotations. "Cropping system" factor was very significant for all measured parameters (Table 2).

Table 2. Analysis of variance (mean square)

Parameters	Cropping system	cv %
Grain yield	3.06**	$3.34 \cdot 10^{-4}$
Plant height	730**	$1.96 \cdot 10^{-3}$
Spikes/m^2	28616**	$2.05 \cdot 10^{-2}$
Earing	66.76**	$8.13 \cdot 10^{-5}$
Test weight	5.36**	$6.05 \cdot 10^{-5}$
Kernels weight	37.13**	$4.24 \cdot 10^{-4}$
Shrilled kernels	130.95**	$1.07 \cdot 10^{-2}$
Protein d.m.	0.14**	$1.76 \cdot 10^{-5}$
Gluten d.m.	0.14**	$2.51 \cdot 10^{-5}$
Gluten index	1.54**	$8.87 \cdot 10^{-4}$
S.D.S.	38.16**	$1.75 \cdot 10^{-3}$
Grain moisture	$3.4 \cdot 10^{-3}$**	$2.66 \cdot 10^{-6}$
Ash d.m.	$6.5 \cdot 10^{-3}$**	$4.86 \cdot 10^{-6}$

**Significant at P < 0.01.

As far as the bioagronomic parameter is concerned yield of W-V_{gm} cropping system, always statistically different, was double in comparison to field mean (3.63 t/ha vs 1.96 t/ha) (Table 3); higher plant height (+26 cm); very high number of spikelets/m^2 (419 vs 248).

Table 3. Contrast analysis among cropping systems for grain yield and spikes/m^2

	Grain yield				
	W-W	W-V_{gm}	W-V_h	W-V_g	W-F
Grain yield					
W-F	21.8**	100.2**	19.5**	16.9**	
W-V_g	1.13NS	208.3**	0.09NS		
W-V_h	1.72NS	199.6**			
W-V_{gm}	165.1**				
W-W					
Spikes/m^2					
W-F					
W-V_g					0.01NS
W-V_h				0.48NS	0.64NS
W-V_{gm}			188.8**	182.8**	181.9**
W-W		135.4**	0.18NS	0.36NS	0.39NS

**Significant at P < 0.01; NS: not significant.

Among all other theses W-F rotation, both for fertilized and non fertilized, was always more productive (2.01 t/ha). On the contrary W-W (monocropping), even if it was statistically different from W-V_g and W-V_h, reached the lower field values (1.08 t/ha) (Fig. 1).

Influence of cropping system on the vegetative-productive cycle was very evident (Fig. 2). Green manured plots were characterized by a very late earing stage (+13 d in comparison to W-W), on the contrary all the other plots, due to an evident water stress, were subjected to an extreme early earing stage. Both W-V_{gm} cropping systems, due to an extension of the vegetative-productive cycle, profit of late rainfall, ulteriorly exalting productive performances. Contrast between fertilization rate (0 and 80 kg/ha) was non statistically significant. In the field thermopluviometric conditions, nitrogen fertilization did not improve durum wheat performances; on the contrary on W-V_g thesis the higher fertilization level reduced yield. (-0.16 t/ha). On green manured cropping systems, on the contrary, the highest fertilization level determined a yield increase even if not statistically different (0.4 t/ha). Durum wheat commercial parameters showed a less evident behaviour in relation to cropping systems. The field mean test weight was 84 kg/hl and plots N0, W-V_{gm}/80 and W-F/80 reached the highest values.

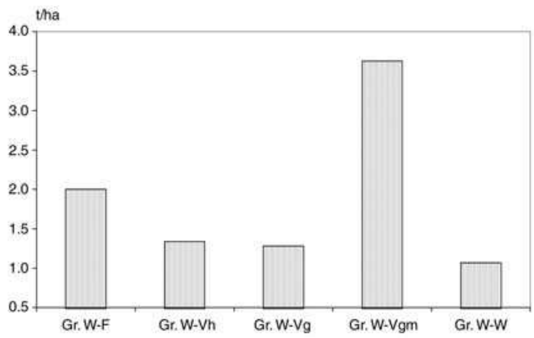

Fig. 1. Durum wheat grain yield (groups average).

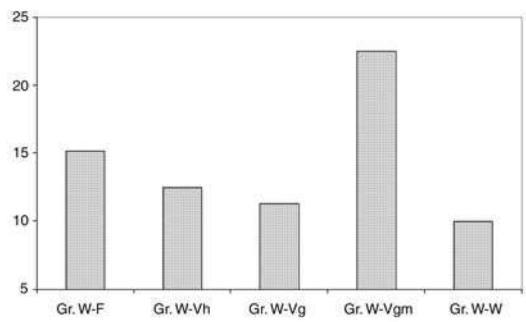

Fig. 2. Earing stage (groups average).

The "cropping system" factor significantly influenced kernel weight; kernel weight of W-V_{gm}/80 cropping system was, in fact, about 44.2 g, in comparison to about 41 g of both bare fallow plots and non fertilized green manure thesis. All other plots determined lower values, especially durum wheat monocropping (W-W) (34 g).

Higher commercial characteristic values determined by W-V_{gm}/80 cropping system is justified by low shrivelled kernel percentage (8.1%) in comparison to a 22.6% value (field average) characterizing a high water stress status.

As far as qualitative aspects are concerned, green manured thesis, characterized by a low shrivelled kernel percentage, showed an high protein content (15.1% d.m.) and gluten (13.8% d.m.) both comparable to results due to fertilized plots (N80) in which grain yield per hectare was slightly lower.

Conclusions

Production of the green manured cropping system (W-V_{gm}), in the trial conditions characterized by very low rainfall, resulted extremely positive, determining grain yield higher than conventional cropping systems.

Productive difference of green manured cropping system (W-V_{gm}), in comparison to bare fallow cropping system, put in evidence yield increase due to leguminous biomass incorporation in the soil and consequently to cropping system water use efficiency increase, more than previous crop water use and consumption.

The excellent grain yield was also characterized by a good commercial and qualitative grain level.

Leguminous green manure seems to be able to improve cropping system sustainability both in terms of a higher yield stability (soil organic matter buffer) in relation to climatic trend, and energetic input reduction.

Cropping system sustainability improvement, reducing the climatic and pedological variability effects, determine an increase of yield stability over time allowing the possibility to obtain homogenous and consistent durum wheat stocks that are strongly sought by industry.

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