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Effect of organic and mineral fertilization on faba bean (*Vicia faba* L.)

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ABSTRACT

The aim of this research was to evaluate the effect of various combinations of organic and/or mineral fertilizers on faba bean (*Vicia faba* L.) to identify the best treatment for balancing yield, seed quality and composition and soil fertility maintenance over time. Wet olive pomace, an olive-mill by-product very abundant in olive oil producing countries, was used for fertilization trials. The use of wet olive pomace at 140 Mg ha^{-1}, combined with half of the conventional N, P, and K dose of mineral fertilization, allowed to achieve the same faba bean productivity of full mineral fertilization. Higher levels of wet olive pomace did not induce further productivity increase. The highest protein content in dry faba bean seeds (276.05 g kg^{-1}) was detected at full mineral fertilization. Phenolic compounds and antioxidant activity showed an opposite trend and tended to be lower in case of full mineral fertilization alone, whereas were higher in unfertilized control and in the trials fertilized with combinations of half mineral fertilization and olive pomace. The latter fertilizing condition also allowed to suppress the infesting flora. The use of wet olive pomace for agricultural purposes could therefore represent an environmentally friendly support to mineral fertilization, adding value to a by-product.

1. Introduction

Legumes and legume based foods are an important and sustainable source of nutrients for human diet, particularly carbohydrates and proteins (Vioque et al., 2012; Summo et al., 2016). Moreover, legumes contain also bioactive substances, such as phenolic compounds, which are the object of study for their antioxidant activity and healthy features (Campos-Vega et al., 2010; Ramos, 2007).

Among legumes, faba bean (*Vicia faba* L.) seeds are a traditional staple food in all the Mediterranean Basin, as well as in India, Pakistan and Cina. In addition, their consumption has increasing also in Western Countries as fresh (green seeds), frozen or canned product (Nadal et al., 2005; Köpke and Nemecek, 2010). Faba beans are also largely used for animal feed more than for human consumption (Vioque et al., 2012). In fact, although faba beans contain some anti-nutritional compounds such as tannins, vicine and convicine (Crépon et al., 2010), they have a good nutritional value being rich of proteins, carbohydrates, fiber, vitamins, and mineral salts (Ofuya and Akhidue, 2005).

Faba bean plays also an important agronomical role being able to fix atmospheric nitrogen and to act positively as a break crop in intensive cereal-dominated crop rotations, also preventing soil erosion (Köpke and Nemecek, 2010). However, in spite of valuable nutritional and agronomical performances, the faba-cultivated world surface halved from 1965 to 2007 (Rubiales, 2010), probably due to low productivity, below its potentiality (Kubure et al., 2016).

In legume crops, important factors influencing yield are seeding density (Yohannis et al., 2015) and phosphate contribution (Tekle et al., 2015). The latter, in particular, plays an important role in plant growth, root development and nodulation, nitrogen fixation, and formation of glycolate phosphate involved in photosynthesis (Kubure et al., 2016).

Mineral fertilization of soil, therefore, is certainly useful for improving yield. However, this type of fertilization could not be the most effective and balanced treatment in view of maintaining soil fertility over time (El-Metwally and Abdelhamid, 2008). On the contrary, fertilizers rich in organic matter improve the physico-chemical and biological characteristics of soil, contributing to increase its fertility and reintegrating the organic substances which undergo natural mineralization processes.

Both mineral and organic methods of fertilization are characterized by advantages and disadvantages, on which a lively debate has been going on for a long time. Currently, organic fertilization with low chemical input is preferred.

Wet olive pomace, either composted or as such, has been proposed as fertilizer in combination with mineral elements (N, P_2O_5 and K_2O; Cucci et al., 2008, 2013). This olive-mill by-product, very abundant in olive oil producing countries, determines not only the mobilization of

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Table 1
Particle size distribution, chemical properties and hydrologic properties of the soils where the trials were carried out.

Parameters		Units	Values
Particle-size analysis			
Total sand	2 > ø > 0.02 mm	($g\ kg^{-1}$)	580
Silt	0.02 > ø > 0.002 mm	($g\ kg^{-1}$)	301
Clay	ø < 0.002 mm	($g\ kg^{-1}$)	387
Chemical properties:			
Total Nitrogen (Kjeldahl method)		($g\ kg^{-1}$)	−1.1
Available phosphorus (Olsen method)		($mg\ kg^{-1}$)	23.5
Exchangeable potassium ($BaCl_2$ method)		($mg\ kg^{-1}$)	262
Organic matter (Walkley Black method)		($g\ kg^{-1}$)	18
Total limestone (Dietrich-Fruhling method)		($g\ kg^{-1}$)	24
Active limestone		($g\ kg^{-1}$)	1.4
ECe		($dS\ m^{-1}$)	0.4
ESP			0.8
pH			7.4
Cation exchange capacity ($BaCl_2$ method)		($meq\ 100\ g^{-1}$)	20.9
Hydrologic properties			
Field capacity		($g\ kg^{-1}$ d.w.)	246
Wilting point (-1.5 MPa)		($g\ kg^{-1}$ d.w.)	125
Bulk density		($t\ m^{-3}$)	1.5

ECe: saturation extract electrical conductivity; ESP: exchangeable sodium percentage; d.w.: dry weight.

organic resources already present in the soil, but also an increase in effectiveness of mineral fertilizers (Cucci et al., 2013). The use of wet olive pomace also greatly reduces the accumulation of nitrates in plants and soil, and can have suppressive action towards weeds and some phytopathogenic agents (Cucci et al., 2008).

In this frame, the aim of this research was to evaluate the effect of various combinations of organic and/or mineral fertilizers on faba beanto identify a treatment able to balance yield, seed quality and composition and soil fertility maintenance over time.

2. Materials and methods

2.1. Plant cultivation

Faba bean (*Vicia faba* var. *major* Harz) cv. Aguadulce Supersimona was grown in 2015/16 at the experimental station of DISAAT Department, University of Bari 'Aldo Moro', sited in Bari, Italy, in a rotational crop system in alternation with durum wheat. The cultivation was carried out in cylindrical pots (0.72 m diameter and 0.60 m high), filled with 293 Mg of sandy-loam soil having good fertility, whose main physico-chemical characteristics are reported in Table 1. A randomized block experimental system with six replications was adopted and seven treatments were compared: unfertilized control (T) and 6 fertilized trials: 3 with mineral fertilization (carried out with $(NH_4)_2SO_4$, K_2SO_4, and with P in a form varying according to the treatment, at the dose usually adopted for faba bean cultivation in Southern Italy, i.e. 30 kg N ha^{-1}, 80 kg K_2O ha^{-1}, and 80 kg P_2O_5 ha^{-1}), and 3 with organic fertilization (i.e. 70, 140, and 210 Mg ha^{-1} of non-composted wet olive pomace, coded S1, S2, and S3, respectively) combined with half of the dose of mineral fertilizer (15, 40, 40 kg ha^{-1} for N, P_2O_5, and K_2O, respectively). The main characteristics of wet olive pomace are reported in Table 2. In the three trials treated with mineral fertilization, P_2O_5 was given as: simple superphosphate (C1); Fosfactyl, Top-Phos MPPA D-Coder, 3–22 of N and P_2O_5, respectively, with P protected by activated polyphenolic molecules (C2); simple superphosphate and Top-Phos 50:50 (C3). The fertilizer treatments compared in faba bean trials are reported in Table 3.

Sowing was carried out on November 19, 2015, at a density of 12 plants m^{-2}, distributed on two rows. As for irrigation, when 50% of the maximum available water was lost (determined by evapotranspiration method), plants were irrigated with a volume of water calculated to restore field capacity in the whole soil mass contained in each pot.

Table 2
Physico-chemical properties of wet pomace used in the fertilization trials.

Parameter	Value
pH	5.36
Moisture ($mg\ kg^{-1}$ d.w.)	549.0
Organic C ($g\ kg^{-1}$ d.w.)	525.7
Phenols ($mg\ g^{-1}$ d.w.)	12.47
Fats ($g\ kg^{-1}$ d.w.)	100.2
Total N ($g\ kg^{-1}$ d.w.)	10.8
Total P ($g\ kg^{-1}$ d.w.)	2.1
Total K ($g\ kg^{-1}$ d.w.)	13.6
Zn ($mg\ kg^{-1}$ d.w.)	19.00
Mn ($mg\ kg^{-1}$ d.w.)	11.00
Cu ($mg\ kg^{-1}$ d.w.)	16.90
Cr, Ni, Co, Pb, Cd ($mg\ kg^{-1}$ d.w.)	< 1

d.w.: dry weight.

Seed harvesting, as well as the determination of the main morpho-physiological and quality parameters, was carried out on 3 plants per pot at the stage of fresh pods (starting from April 14 - when the *hilus* that binds the seeds to the pod began to turn dark - to May 9, for a total of 4 collections), and 3 plants per pot at the stage of full ripening (almost dry seeds, on June, 21). The almost dry seeds were left to dry further in the sun to reach 12% moisture content, and were then milled and submitted to the determination of antioxidant activity, total phenolic compounds and protein content.

2.2. Measure of weed and broomrape growth

The presence of bean broomrape (*Orobanche crenata* Forssk) was monitored, as well as the infesting flora. Bean broomrapes (which appeared at the end of April, when the collection of fresh pods was almost completed) were weeded out, counted (broomrape shoots), dried in oven at 70 °C, and weighed to quantify their dry biomass. Infesting flora was eliminated by manual weeding 80 days after the emergence of faba bean. The weeds from each pot were dried in oven at 70 °C until constant weight was reached, then weighed to quantify their dry biomass.

2.3. Determination of morpho-physiological parameters and grain yield

The chlorophyll index was determined when plants were close to flowering by means of Chlorophyll Meter SPAD-502 (Spectrum Technologies Inc., Aurora, IL, USA) to characterize the crop nitrogen status. Plant height, number of shoots, shoot dry biomass, number of pods per plant, number of seeds per pod, yield of fresh and dry seeds were also determined.

2.4. Faba bean milling

Dry faba bean seeds were milled to whole meal flour by means of a laboratory mill equipped with a 1-mm sieve (Cyclotec Sample Mill, Tecator Foss, Hillerød, Denmark).

2.5. Moisture content determination

Moisture content was determined at 105 °C by means of an automatic moisture analyzer (Radwag Wagi Elektroniczne, Radom, Poland).

2.6. Protein content determination

Total nitrogen was determined by the Kjeldhal method and results were converted to the crude protein by 5.7 conversion factor (Longobardi et al., 2015).