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Effect of Olive Mill By-products on Mineral Status, Growth and Productivity of Faba Bean

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Abstract: Greenhouse experiments and field trials were carried out during the 1999/2000 growing season at Jordan University of Science and Technology agricultural station to investigate the effects of different levels of olive mill by-products as soil treatments on the nutritional status and growth of faba bean (*Vicia faba* L.). Three levels of Jift and Zebar soil treatments, a chemical fertilizer and animal manure were assigned randomly in a randomized complete block design in triplicate. The Jift:soil 1:12 treatment and 4 L m^{-2} Zebar treatment increased grain yield and biological yield of the faba bean crop. Chemical analyses for inorganic nutrient elements in crop foliage revealed that both Jift and Zebar application resulted in increased nitrogen, potassium, zinc and iron concentrations. There was no significant difference in phosphorus concentration between treated and untreated plants. Olive mill by-products are recommended for use as a soil amendment to improve crop productivity and improve soil chemical and physical properties.

Key words: Faba bean, olive mill by products, organic waste, mineral status

INTRODUCTION

Legumes are considered the most important field crop due to their high nutritional (protein) values (Bahl, 1990; Fageria *et al*., 1990). In fact, legumes are a vital part of the diet in developing countries as a cheap protein source that compensates for the lack of expensive meat products. Faba bean (*Vicia faba* L.) is an economical field crop grown in the Mediterranean region, where it is the most important traditional daily diet item throughout the Middle East (Hamdi *et al*., 1992).

The two major constraints affecting crop production in arid rainfed areas are the chronic water limitations (Amir and Sinclaire, 1996) and low availability of fertile soils (Baethgen *et al*., 1995; Hopkins, 1995; Tisdale *et al*., 1985). The mineral nutrition requirements of plants are traditionally discussed as two separate topics: Organic and inorganic nutrition (Hopkins, 1995). Inorganic nutrition is the acquisition of mineral elements from the soil by plants and the main concern in plant nutrition is the availability of these essential mineral elements to crop plants and the resulting productivity. Farmers add chemical fertilizers to improve soil fertility and to increase the yield of their crop (Leyshon *et al*., 1980). However, extensive applications of fertilizers can be disadvantageous to the environments (Varval and Stevenson, 1987; Kurdali *et al*., 1997). These chemicals may undergo decomposition and may be leached from the soil into ground water and lakes (Dhugga and Waines, 1989). An alternative to chemical fertilizer is organic fertilizer, added to the soil either directly before planting or during crop growth. Organic fertilizers such as animal manure (compost), sod and green manure, compost and sewage sludge may be added to cultivated soil (Splittstoesser, 1990). This practice may improve the physical and biological properties of the soil and provide a source of mineral nutrients (Davidson and Mecklenburg, 1981).

Jordan as a Mediterranean country is characterized by the presence of many olive plantations, with over 10 million trees (Abu-Zriq, 1998). In 1998, Jordan had 197,500 acres planted with olive trees. The average olive production in Jordan is 105,000 tons per year (Abu-Zriq, 1998), most being processed for oil (Anonymous, 1994). This agro-industry produces three main products: Olive oil, a solid residue called Jift and a wastewater called

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Zebar. Jift and Zebar are rich in organic materials and minerals (Nefzaol, 1991). In Jordan, the amount of Jift produced is estimated to be over 100,000 tons per year and the amount of Zebar is about 500,000 m^3 a year (Al-Haiek and Mousa, 1997). Olive mill by-products (OMP) can be utilized in agricultural practices as soil amendments or even as organic fertilizer, but little information exists on the utilization of this organic waste as soil amendments (Hamdi, 1993). OMP are available year round, at low cost. The present study tested the hypothesis that the application of OMP can therefore decrease the production cost of many crops if they can be used instead of chemical fertilizer. The major objective of this study was to determine the effect of OMP (solid and wastewater) soil treatments on the nutritional status and yields of faba bean.

MATERIALS AND METHODS

Greenhouse experiments and field trials were carried out during the 1999/2000 growing season at Jordan University of Science and Technology (JUST) in northern Jordan (32°34' N latitude, 36°01' E longitude and 520 m altitude) to study the effect of different levels of OMP (solid and wastewater) soil treatments on growth, productivity and nutritional status of faba bean. Faba bean (*Vicia faba* L.) cultivar Major was provided by the National Center of Agriculture Research and Technology Transfer (NCARTT), Amman-Jordan. Seeds were planted in the greenhouse and in open fields of JUST. Plants were treated with pesticides as needed. Weeds were controlled manually from the field plots.

Jift and Zebar were incorporated into greenhouse soil and used as soil treatments in open fields. Jift was added to soil at 1:7, 1:9 and 1:12 (vol/vol). Zebar was added to the field plots at the rate of 1, 2 and, 4 L m^{-2} in the top 20 cm of treated soil. Each plot contained 8 rows, with 1 m between plots and 1.5 m between replications. Field plot dimensions were 2×2 m. Plants were grown in a Randomized Complete Block Design (RCBD) and all treatments were replicated three times.

Greenhouse experiments: Faba beans were planted in 4 L plastic pots. Soil was mixed with OMP (Jift and Zebar) before use. Two other soil treatments were also tested: Animal manure at 19.76 tons per ha and inorganic fertilizer (Diammonium phosphate; DAP) at 100 kg per ha. Untreated soil alone served as control. Air temperatures inside the greenhouse did not exceed 22°C and relative humidity was maintained around 65%.

Field trials: The field trial was carried out at the JUST experimental station, which has a Mediterranean climate (mild and rainy in winter and dry and hot in summer). The soil at this site is smectitic, thermic, typic chromoxerert, with a very fine clay texture in the upper 15 cm. The soil pH was 8.1 and organic matter was 16 g kg^{-1} soil. Available P was 4.5 mg kg^{-1} extractable P (Olsen *et al.*, 1954) and the available N was 1 g kg^{-1} soil. Faba bean plants were grown under irrigation.

Measured variables: The yield, yield components and growth characteristic measured were plant height, pod length, seed weight per plant, number of pods per plant and number of seeds per pod. Nitrogen, phosphorous, potassium, iron and zinc concentrations were determined in plant tissues after maturity. Nitrogen analyses were carried out using micro-kjeldhal methods (Ryan *et al.*, 1977). Phosphorus analyses were conducted by the procedure described by Olsen *et al.* (1954). Iron and zinc were analyzed in plant tissue by utilizing atomic absorption photometry (Krentos and Orphanos, 1979).

Soil samples were collected from each plot in the field trial from sub-surface soil at a depth of 15-25 cm. Each soil sample was analyzed for soil pH (526, WTW Multical pH meter) and electric conductivity (EC; LE 539, WTW). Percent Organic Matters (OM) and percent ash content was also determined for each soil sample (Paredes *et al.*, 1987). The data were analyzed by analysis of variance at the 0.05 probability level, followed by Fisher's protected least Significant Difference Test (LSD) to determine the significant differences among the means using the Statistical Analysis System (SAS Institute, Cary, NC).

RESULTS

Greenhouse experiments: Soil treated with Jift and Zebar adversely affected faba bean plant height (Table 1). Seed weight increased with Jift at 1:9 and Zebar at 2 L m^{-2} (4.3 and 4.7 grams, respectively; Table 1). This experiment demonstrated the positive effect of both Jift and Zebar on the nitrogen concentration in faba bean (Table 2). The Jift 1:9 treatment and Zebar 4 L m^{-2} treatment resulted in increased potassium content (3.1 and 3.5%, Jift and Zebar, respectively), while they had negative or no effect on iron concentration (31, 43 mg kg^{-1}, Jift and Zebar, respectively), compared to the fertilizer treatment and untreated control (Table 2).

Field trials: Results of the open field trials were in agreement with the greenhouse results. The plant height, pod length, number of pods per plant and number of seeds per pod increased with all Jift and Zebar treatments (Table 3). Soil treated with Jift resulted in increased seed

Table 1: Effect of soil amended with OMP on greenhouse-grown faba bean plant height, pod length, seed weight per plant and number of seeds per pod[a]

	Vegetative data (cm)				
Treatments	Height	Pod	Seed weight/plant	Pods/plant	Seeds/pod
Control	45.1bc	6.3abc	4.2ab	1.3a	1.1a
Jift:Soil[b]					
1:7	42.2e	6.5abc	3.5 bc	1.9a	1.2a
1:9	43.4de	6.0bc	4.3ab	1.8a	1.6a
1:12	44.5cde	6.8ab	4.0abc	1.4a	1.2a
Zebar:Soil[c]					
4 L m^{-2}	48.4ab	6.2bc	3.3c	1.3a	1.1a
2 L m^{-2}	45.5cd	5.6c	4.7a	1.5a	1.1a
1 L m^{-2}	46.5bc	5.5c	4.2ab	1.7a	1.4a
Fertilizer[d]	48.3ab	7.6a	3.4bc	2.0a	1.7a
Animal manure[e]	49.5a	6.1bc	3.4bc	1.5a	1.1a

[a]Mean followed by the same letter(s) are not significantly different at 0.05% probability levels, [b]Jift added as vol/vol, [c]Zebar added as L m^{-2}, [d]Diammonium phosphate added at 0.099 metric ton ha^{-1}, applied in greenhouse only., [e]Animal manure added at 19.76 metric ton ha^{-1}

Table 2: Effect of soil amended with OMP on greenhouse and field faba bean nitrogen, phosphorus, potassium and zinc concentrations[a]

	Greenhouse					Open field				
Treatments	N (%)	P (%)	K (%)	Zn (mg kg^{-1})	Fe (mg kg^{-1})	N (%)	P (%)	K (%)	Zn (mg kg^{-1})	Fe (mg kg^{-1})
Control	2.5c*	0.21a	2.8c	21a	52b	3.4bc*	0.2b	2.0d	20d	46cd
Jift:Soil[b]										
1:7	3.1bc	0.1 8a	1.5f	21a	27d	3.3bc	0.2b	2.2c	42b	64b
1:9	4.3a	0.20a	3.1b	20a	31cd	3.4bc	0.2b	2.6a	23cd	93a
1:12	3.4bc	0.31a	2.2de	21a	55b	3.1d	0.2b	1.9d	36bc	53c
Zebar:Soil[c]										
4 L m^{-2}	2.4c	0.21a	3.5a	20a	43bc	3.3c	0.2b	2.4b	51a	25f
2 L m^{-2}	3.7bc	0.31a	2.5d	22a	43bc	3.4bc	0.1b	2.0d	37bc	61b
1 L m^{-2}	3.0bc	0.30a	2.2de	20a	54b	3.9a	0.2a	2.4b	29bcd	33e
Fertilizer[d]	4.8a	0.25a	2.0ef	21a	48b	-	-	-	-	-
Animal manure[e]	3.7b	0.31a	1.6f	22a	81a	3.6b	0.1b	1.9d	23cd	40d

[a]Mean followed by the same letter(s) are not significantly different at 0.05% probability levels., [b]Jift added as vol/vol, [c]Zebar added as L m^{-2}, [d]Diammonium phosphate added at 0.099 metric ton ha-applied in greenhouse only., [e]Animal manure added at 19.76 metric ton ha^{-1}

Table 3: Effect of soil treatments on field faba bean plant height, pod length, number of primary branches per plant, number of pods per plant, number of seeds per pod and harvest index[a]

	Vegetative data (cm)				
Treatments	Height	Pod	Branches/plant	Pods/plant	Seeds/pod
Control	72b	9c	2.8a	15d	2.7b
Jift:Soil					
1:7	75a	10bc	2.8a	22a	3.5a
1:9	69c	12a	2.9a	20b	3.2ab
1:12	77a	8d	2.6a	22a	2.9ab
Zebar:Soil[c]					
4 L m^{-2}	66d	8d	3.0a	15d	2.6b
2 L m^{-2}	75a	8d	2.9a	12e	2.8b
1 L m^{-2}	66d	10b	2.8a	19c	3.1ab
Animal manure[d]	71bc	10b	2.8a	15d	2.9ab

[a]Mean followed by the same letter(s) are not significantly different at 0.05% probability levels, [b]Jift added as vol/vol, [c]Zebar added as L m^{-2}, [d]Animal manure added at 19.76 metric t ha^{-1}

and biological yield of faba bean (Fig. 1). There were significant increases in nitrogen content, potassium and zinc concentrations in Jift and Zebar soil treatments (Table 2).

Assessment of OMP on soil: Soil treated with Jift and Zebar had improved chemical and physical properties. Percent OM and EC increased with all Jift treatments (Table 4). EC increased with all Jift rates (Table 4). On the contrary, Zebar had no effect on soil OM or percent ash in treated soil (Table 4) and only a slight increase in EC was shown with Zebar (Table 4). Soil pH decreased with Jift and Zebar soil treatments from 8.38 in untreated soil to 7.86 and 8.08, respectively (Table 4). Jift and Zebar both have good amounts of nitrogen, phosphorus and other minerals (Table 6); both are acidic and Jift has a high percent of organic mater (Table 5).

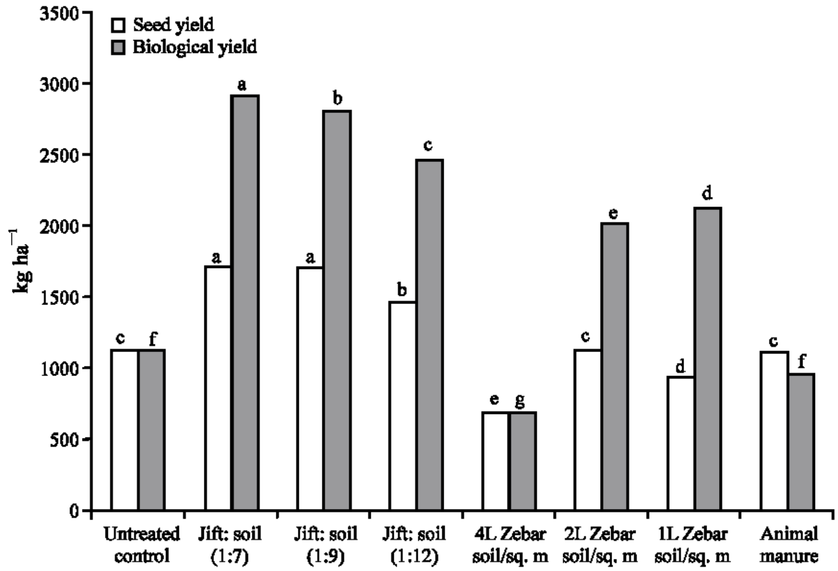

Fig. 1: Effect of soil amendment with OMP on field-grown faba bean seed yield and biological yield

Table 4: Chemical analyses of soil amended with OMP: percent OM, percent ash, EC and pH before and after planting in open field trial

	Before planting				After planting			
Treatments	OM (%)	Ash (%)	EC (ds m^{-1})	pH	OM (%)	Ash (%)	EC (ds cm^{-1})	pH
Soil only	0.92	90.72	0.566	8.38	0.89	90.63	0.89	8.27
Soil treated with Jift 1:7	1.27	87.24	0.690	7.95	1.31	86.68	1.84	8.08
Soil treated with Jift 1:9	1.22	86.71	0.840	7.86	1.01	89.88	0.84	8.18
Soil treated with Jift 1:12	1.00	89.96	0.720	8.08	1.06	88.98	0.97	8.07
Soil treated with Zebar 1 L m^{-2}	0.95	90.42	0.575	8.41	0.89	89.51	0.99	8.23
Soil treated with Zebar 2 L m^{-2}	0.89	91.03	0.630	8.45	0.92	90.02	1.24	8.18
Soil treated with Zebar 4 L m^{-2}	0.88	91.14	0.570	8.42	0.88	90.52	0.98	8.23
Soil treated with Animal manure	0.92	90.71	2.695	7.91	1.01	89.91	-----	7.80
Soil treated with fertilizer[a]	0.94	90.59	0.533	8.48	0.94	89.53	0.91	8.16

Table 5: Mineral and chemical analyses of olive mill solid waste (Jift) and wastewater (zebar)

Olive mill by-product type	N (%)	P (%)	K (mg kg^{-1})	Zn (mg kg^{-1})	pH	EC (ds cm^{-1})	OM (%)	Ash (%)
Fresh Jift	2.4138	0.115	1000	0.622	5.21	4.20	93.51	3.513
Fresh Zebar	0.1099	0.175	520.0	0.658	7.57	4.24	0.671	0.949

DISCUSSION

In countries like Jordan, where olives are a major crop, OMP are probably used as soil amendments for one purpose or another (Al-Haiek and Mousa, 1997). Because these products contain phytotoxic components (Estaun *et al*., 1985) and applications may have been uncontrolled, farmers and growers have developed negative attitudes against their usage in agriculture as soil treatments. However, the present investigation demonstrated that grain yield and biological yield of faba beans were either increased or not affected at the lower applications of Jift at 1:12 and Zebar at 1 L m^{-2} (Fig. 1). These results confirm the findings of Tattini *et al*. (1991), in which they reported that peach (*Prunus persica*) and olive (*Olea europaea*) yields increased with soil application of olive mill waste materials. This effect may be due to the organic matter present in Jift and its metabolites produced by soil microorganisms. At those lower rates and possibly with the duration of the experiments, the effects of the phytotoxic components were minimized. Those results are consistent with the results obtained by El-Koumey and Abu-Agwa (1993), who found that soil application of chicken manure and waste-water increased the yield of cowpeas (*Vigna sinesist*).

One of the limiting nutritional aspects in agriculture is the availability of nitrogen in the soil and its nutritional status within the plant. Soils treated with Jift and Zebar at all rates showed elevated nitrogen content in the soil and in the foliage of faba bean plants, in contrast to untreated soil (Table 1 and 2). Hence, incorporation of Jift and/or Zebar into agriculture soil is beneficial to soil fertility because nitrogen availability is increased. This could be attributed to mineralization processes in soil and solubilization of organic nitrogen from OMP organic matter by soil microorganisms, accompanied by increased activity of Rhizobia (nitrogen fixing bacteria). Havlin *et al.* (1999) found that adding organic matter to soil had a positive effect on soil microorganisms, which is in agreement with the present results. Increased nodulation on faba bean roots was observed, which confirm similar results of El-Koumey and Abu-Agwa (1993).

One of the significant findings here is that phosphorus levels in treated soil and plant foliage (Table 1 and 2) stayed very close to the control (0.2%), a condition encouraging for mychorrhizal establishment, as previously reported by Aqeel (2001). The static phosphorus levels could be due to the fact that organic matter needs a rather long time to be degraded by soil microorganisms before absorption by plant roots. Al-Saket and Al-Moumani (1989) demonstrated this kind of process during their work on the effect of vasicular arbuscular endomycorrhiza on olive seedling and its relation to the absorption of mineral nutrients from Jift treated soil.

There was a significant increase in potassium concentrations in the foliage of faba beans grown in soil treated with all Jift and Zebar rates in the greenhouse and under field conditions (Table 1). This increase in potassium levels might be attributed to the relatively high content of potassium in OMP (1000 mg kg^{-1} Jift, 520 mg kg^{-1} Zebar) (Table 6). The same result was reported by Al-Saket and Al-Moumani (1989). Another explanation for this increase in potassium is the increase in Cation Exchange Capacity (CEC) of soil treated with Jift and Zebar, which has a direct effect on the increased availability of potassium in soils (Havlin *et al.*, 1999).

The increased concentrations of micronutrient elements (zinc and iron) in all treatments was observed (Table 1 and 2) and could be attributed to increased microbial activity in Jift and Zebar soil treatments, which produce natural organic chelaters that enhance micronutrient availability. This increase in zinc and iron concentrations might also be related to the drop in soil pH, because of the acid nature of the olive mills waste material (Table 3). These results are consistent with results obtained by Perez and Gallardo-Lara (1993). OMP enhanced microbial activity and released some sort of natural organic chelating or solubilizing agents, which were previously depicted by Tisdale *et al.* (1985). The present investigation therefore opens an avenue for future work to test the efficacy of Jift and Zebar amendments to different kinds of soil.

Jift and Zebar exhibited an allelopathic effect on cereal crops to a greater extent than on legumes in general (Capasso *et al.*, 1995). This allelopathic effect was previously documented by Hameed and Foy (2000) and they postulated that it could be used as a potential bioherbicide. This is further emphasized by our observation on the decrease in weeds in the pots and the field plots.

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