Agronomic and Economic Benefits of the Application of Olive Pomace and Harvest Residues Composted with Bioaugmentation on Olive Orchards

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Abstract

Biohumus was obtained by composting olive pomace and harvest residues with bioaugmentation. Bioaugmentation is inoculating into the population of native bacteria of the residue specific bacteria to increase the range and velocity of its organic reduction and obtain high quality compost called biohumus. This work summarizes results of biohumus application on olive orchards where soil and vegetable productivity parameters as well as economic feasibility were evaluated. After six years of 9 kg per plant biohumus application to an olive orchard in Pomán, Catamarca province, it was verified that the large amount and diversity of microorganisms incorporated with the biohumus played a fundamental role in fixing environmental N and providing nutrients to the olive plants, explaining its excellent development, sanity and productivity. Moreover, it was also demonstrated that the cost/benefit ratio was strongly positive being the direct cost of biohumus fabrication and application 12 to 15% of any chemical fertilization. Biohumus was also utilized as 50% of substrate in an olive nursery in Catamarca. In this essay more than a 30% development increase was attained. Together the results showed that biohumus generated a substantial improvement of the physical, chemical and microbiological soil properties and greater orchard development and productivity, replacing the chemical fertilization at a much lower cost.

INTRODUCTION

Microorganisms are essential for the vegetal development, producing the biochemical processes for the production of nutrients and its capture by the rhizomes. Organic matter (OM) is essential for the existence of microorganisms who feed themselves with its components, some generating enzymes to colloidize different fractions of the OM and others transforming the colloids in polysaccharides and producing nutrients for plants (Sánchez-Yañez et al., 2011). OM from farm and farm industries generated in Cuyo and the northeast of Argentina are extremely valuable for its incorporation, well composted, to the arid local soil.

OR should not be applied crude or burned for energy. Phytotoxic effects on plants of applying crude OM are very important, producing greater weakness to plague attacks, because of less availability of N and O being consumed by bacteria to decompose OM; phytotoxins production like benzoic and phenilacetic acids during the first 2 months; presence of toxic organic acids of low molecular weight like acetic, propionic and butyric, and high content of cellulose generating N immobilization (Chen et al., 1997). Till recently in Spain, olive pomace (alperujo) was mainly used as fuel for clean energy generation. But the recent detection of aromatic polycyclic hydrocarbons generated during the drying of the by-product for the extraction of residual oil with dissolvents, along with the contaminating impact of combustion gases, is driving to composting of olive pomace (Cegarra Rosique, 2004), nevertheless still insignificant.

We call biohumus (Bh) the product obtained by composting OR with bioaugmentation with Solbío technology. Bioaugmentation is the reinforcement of the native bacteria population present in the residue adding specific bacteria to improve the ranges of organic reduction, using aerobic and facultative bacteria (Kavitha et al., 2007).

Between other effects, Bh increases the humic and fulvic acids quantity and quality (Vargas-García et al., 2006; Zimin Wei et al., 2007), eliminates pathogens through competition with facultative bacteria and antibiotic generation (Hadar and Mandelbaum, 1992), assures a substantial reduction of flies during composting, cuts to half the production time (Cariello et al., 2007) and improves soil sanity and therefore of plants (De Ceuster and Hoitking, 1999; Vargas García and Suárez Estrella, 2007).

The objective of this work is to show how biohumus nourishes olive plant with competitive production and application costs detailing 6 years soil and foliar measurements in an olive orchard and promotes plant development with its use on young olive plants in a nursery.

MATERIALS AND METHODS

Biohumus was produced in Olivares de Pomán, Catamarca province, Argentina, by composting with bioaugmentation olive pomace (*alperujo*), harvest residues and bovine manure, using as inoculant Solbio BC (Fig. 1).

To avoid the dispersion of the pomace due to its high water content, a receptacle was prepared with old pomace borders 40 cm high and 2 m separation, long as needed, where olive orchard residues were deposited, followed by olive pomace. Once the receptacle was full, the windrow was formed with help of a 90 to 100 cm high leveler pushing the borders towards the center and adding up to 50% manure. With the windrow turner (Fig. 2) the windrow was mixed. Inoculation of Solbio BC was done with a fumigator (Fig. 3), the windrow was turned once more and humidity was maintained between 40 and 60%. Homogenation turns were made about 15 and 45 days later. The biohumus was mature after 60 days of the inoculation of the Solbio BC.

Solbío BC Content

Benefic bacteria: around $2.1*10^9$ UFC/g. Specially *Bacillus amyloliquefasciens*, *Bacillus subtilis* and *Bacillus licheniformis.* Vitamins: biotine, pholic acid, fulvic acid, B, B2, B3, B6, B7, B12, C and K, aminoacids, vegetable and animal proteins, yucca *schidigera* extract, marine algae extract, humic acids, leonardite derivates, natural sugar, dextrose, organic wheat or corn bran.

Olive Orchard "Olivares de Pomán"

This is a 550 ha organic intensive olive orchard in Pomán, Catamarca province, with its olive oil factory. Biohumus has been applied for 6 years at a rate of 4 t/ha or 7.2 kg/plant.

This amount has been decided according to the following reasoning: for an olive yearly production of 10.000 kg/ha and a density of 555 plants/ha, each tree produces 18.02 kg of olives with a weight of 3.6 kg of dry material, that is 2 t/ha. After oil production, nearly all of its weight becomes pruning waste (pomace). Once transformed into biohumus, the dry material with 40% humidity that will return to the orchard represent 6 kg/tree as minimum application, that is 3.3 t/ha. Adding harvest residues and manure, 4 t/ha of biohumus with 40% humidity can be applied. Average annual nutrients measured in this biohumus are 0.91% N, 0.19% P, 1.15% K and 0.67% Mg, that applied at the rate of 4 t/ha are 32 kg N, 7 kg P and 40 kg K (Table 4).

Soil samples were taken every year in the same places. The orchard was divided in 6 lots. In each lot samples were taken at 0-30, 30-60 and 60-90 cm depth, under de water bulb, the watered periphery and in the middle between rows. Nutrients in each sample were analyzed. The average of all samples along 6 years are shown in Table 6. For foliar analysis 200 g samples were taken from 4 trees in each area of the soil analysis, in December when the fruit stone gets hard, at its equatorial height and from the 4 cardinal points. The 6 compensated samples were analyzed during 6 years and their average is shown in Table 7.

Comparative Costs and Investments

Investment and operating costs for the production of the biohumus were taken from the accounting of the company. Costs of production and application of biohumus include items also existing with no composting costs, like residues loading and transport to its disposal location (Table 2). Chemical fertilizing costs were calculated at market value. The comparison between the hypothetical chemical fertilization and biohumus was calculated based on the nutrients need shown in Table 3.

Nursery "Vivero Los Aromos"

In the nursery Los Aromos in Catamarca, an essay on olive young plants was carried out. The purpose of the essay was to compare the development of young olive plants implanted in three different substrates: (1) the commonly used substrate by the nursery, (2) 100% biohumus and (3) a 50% mixture between both. Young 'Arbequina' and 'Manzanilla' plant samples were prepared, each with 100 plants. Monthly height measurements of 20 plants of each sample, randomly chosen the first measurement, were made between January and September 2011. The average height was calculated.

RESULTS AND DISCUSSION

Olive Orchard "Olivares de Pomán"

Tables 5 and 6 show that nutrients in soil and foliage are satisfactory as average of 6 years analysis, with the indicated kg/ha fruit production, being total plant extraction of N, P and K per ha and year around 90 to 120 kg of N, 50 kg of P and 130 kg of K.

Taking into account that the original west Catamarca soils are a sand support, it is concluded that the incorporation of large amounts and diversity of microorganisms with the biohumus plays a fundamental role in the nutritional balance of the orchard by fixing atmosphere N and transforming the OM incorporated to the soil also by pruning, grass, leaves and other OR in direct use nutrients for the olive plants, it modifies favorably the original soil condition increasing its hydric retention capacity and cationic exchange capacity (CEC), attenuating salinity, pH and temperature extremes, explaining its good development, sanity and productivity.

Comparative Costs and Investments

Production and application costs for a Bh volume per plant we consider adequate, is much lower than the average chemical fertilization in developed olive orchards, already at its initial application. On year 1 it is 29% lower, on year 2 it goes down to 48% and from year 3 on the cost is 86% lower than chemical fertilization (Table 3).

Investments for Bh production are modest because those more expensive, like tractor, already exist for other purposes: tractor with double gear and creep speed, chutes and residue wagons, loader shovel, 90/100 cm high leveler, fumigator, windrow turner, watering tank, fertilizer. The net investment is around US$ 29.000 (Table 4).

Nursery "Vivero Los Aromos"

At the end of the essay it was verified that young plants of sample (3) had a 37% greater development compared to the (1) sample showing significant sanity characteristics (Table 7). Sample (2) showed 19% less development that sample (1), with toxicity manifestations in the plants' foliage because of salts excess. Best percent of biohumus to be used needs further research.

CONCLUSIONS

The composting with bioaugmentation of olive pomace, using the Solbío technology, results in an organic fertilizer we call biohumus which applied to olive orchards and olive young plants has demonstrated its capacity to improve the physical, chemical and microbiological characteristics of the soil increasing plant development and productivity as much as 30%. Also an environmental problem is solved by transforming a contaminating industrial residue in a useful product with high biological and nutritional value; the self-sustainability in time of the production system is promoted given the inexistence of an energy external subsidy and allows organic product certification improving the company's' commercial possibilities. The production and application of biohumus is cost effective, allowing the replacement of chemical fertilization.

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Tables

Table 1. Macro and micro nutrients in different residues.

	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	B (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
Olive pomace	1.72	0.20	1.88	1.51	1.67	40.5	5.10	63.9	29.8	10.7
Vignard pomace	2.78	0.39	1.80	0.88	0.25	51.6	8.80	69.0	33.2	17.4
Olive harvest res.	1.80	0.11	0.88	1.88	0.14	20.7	4.00	39.6	18.5	8.0
Poultry bed	2.47	1.48	1.18	10.8	0.04	86.9	29.0	15.1	98.6	57.5

Table 2. Biohumus production and distribution direct annual costs per m^3 in US$ dollars with no VAT.

Detail	Units	Quantity/m^3	US$/unit	Cost US$/$m^3$
Bed forming	Hs m[a]	0.016	24.30	0.39
Pomace transport from factory	Hours	0.100	23.30	2.33
Harvest residues transport	Hs m	0.045	20.60	0.93
Windrow forming	Hs m	0.016	24.30	0.39
Windrow turning	Hs m	0.008	23.30	0.19
Watering energy	Hours	0.013	13.70	0.18
Watering handcraft	Hours	0.032	13.70	0.44
Solbio BC inoculation	Hs m	0.008	24.30	0.19
Solbio BC	per m^3		9.60	9.61
Biohumus load on fertilizer	Hs m	0.013	24.30	0.32
Biohumus application	Hs m	0.360	23.30	8.40
Total cost (US$ with no VAT)				23.36
Pomace transport from factory				2.33
Harvest residues transport				0.93
Less previously existing costs				3.35
Biohumus net cost				20.01

[a] Means hours machine.

Table 3. Comparison between biohumus production and application costs and chemical fertilization costs.

Nutrient	Bioh.[a] (kg/t)	Bioh. nutr. contr.[b] (kg/ha)	Plant nutr. req.[c] (kg/ha)	Nutrients costs (US$/ha)		Total fertilization costs with yearly reduction of chemicals and 4 t/ha biohumus (US$/ha)		
				Chemical	Bioh.	Year 1	Year 2	Year 3
N	9.1	36	95	253		156	78	
P	1.9	8	25	91		64	32	
K	11.5	46	65	215		63	31	
Mg	6.7	27	6	17				
Totals				576	80	363	221	80

[a] Biohumus; [b] Biohumus nutrient contribution; [c] Plant nutrient requirements.

Table 4. Biohumus production and application necessary investments in US$ dollars with no VAT.

	US$	Observations
Truck for pomace and harvest residues transport		Already available
90 HP tractor with 4 WD and ultra slow	30.000	
Charging shovel		Already available
90 cm high leveler	1.400	
Windrow turner	13.300	
Fumigator for inoculation		Already available
Fertilizer	10.300	
Total	55.000	

Table 5. Six years average soil analysis 2007 to 2012.

	pH	Ce (dS m^{-1})	Na sol. (Meq L^{-1})	K sol. (Meq L^{-1})	SAR[1]	N (%)	P (ppm)	OM (%)
Arbequina	8.60	0.59	3.98	0.27	2.14	0.03	10.52	0.52
Picual	8.93	1.00	7.18	0.21	3.72	0.04	11.32	0.89
Coratina	8.60	0.61	4.37	0.27	1.82	0.02	10.72	0.51

[1] Sodium adsorption ratio.

Table 6. Six years average foliar analysis period 2007 to 2012.

	N	P	K	Ca	Mg	Fe	Cu	Mn	Zn	B
			(%)					(ppm)		
ARB[a]	1.58	0.12	0.80	1.95	0.16	55.58	25.22	46.50	34.00	33.33
PIC[b]	1.23	0.10	0.52	2.24	0.13	51.13	19.30	56.08	34.35	26.83
COR[c]	0.90	0.07	0.67	1.58	0.19	61.30	15.28	43.40	41.40	20.20

[a] 'Arbequina'; [b] 'Picual'; [c] 'Coratina'.

Table 7. Average high of young olive plants measured in year 2011 (in cm).

	Israely Manzanilla			Arbequina		
	03/03	11/05	27/09	03/03	11/05	27/09
Biohumus	16.00	18.95	29.50	17.50	24.50	38.40
50%bh/50%NS[1]	05.00	37.50	55.30	17.50	41.25	60.70
Nursery substrat	17.50	24.15	45.80	17.50	29.95	39.40

[a] 50% biohumus and 50% nursery substrate.

Figures

Fig. 1. Biohumus windrows in Olivares de Pomán, Catamarca, Argentina, during composting.

Fig. 2. Windrow forming with turner (1 m high and 2 m at the base).

Fig. 3. Inoculation of Solbio BC for bioaugmentation.