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Agronomic valuation of olive pomace obtained by different extraction systems

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ABSTRACT

Olive pomace from the three extraction systems: the traditional press system, the two-phase continuous system and the three-phase continuous system from the city of Tahla (Morocco), have significant levels of nitrogen and phosphorus fertilizers, a large amount of organic matter and a slightly acidic pH (5.9). Their contribution to the sandy soil of Salé city has a positive effect on stem size, number of leaves and leaf area of bean plant. The addition of pomace has increased the dry matter weight of the aerial parts of the bean. However, the large proportion of these olive pomace is generally not properly valued. The comparative study of the pomace obtained by different extraction systems gave a particularity to the pomace from the two-phase system, given its richness in fertilizing elements; in fact it allowed an optimal development of *Vicia fabae*.

***Key words**: Olive pomace, Agronomic valorization, Soil amendment*

Introduction

The olive oil extraction process is widespread, not only in Mediterranean countries, but also in Argentina, Australia and South Africa, which have recently intensified olive cultivation (Roig *et al.,* 2006)

In Morocco, the olive tree is the main fruit species planted. It is present throughout the national territory because of its ability to adapt to all bioclimatic stages (Chemonics, 2006). As a result, Morocco is one of the world's major olive oil producers, contributing 5% of the country's gross domestic agricultural product (Moroccan Ministry of agriculture, 2016).

In addition to olive oil, olive crushing produces a large quantity of by-products, namely olive mill wastewater and pomace, which are released directly into the natural environment, resulting in catastrophic pollution of the soil, watercourses and groundwater. On the other hand, the recovery of these by-products constitutes a potential source of additional income that can contribute to improving the profitability of olive farms. Indeed, pomace can be used as fuel, livestock feed, fertilizers and thermal insulation in some building materials.

In the Mediterranean basin, large areas suffer from carbon deficiency and loss of organic matter, which is considered to be the main cause of soil degradation in these regions. In addition, olive pomace has high organic matter content (70%), so it can improve the agronomic quality of these soils (Abu-Zreig *et al.,* 2002). Other studies have shown that the use of pomace can improve the organic carbon content of the soil (Lopez-Pineiro *et al.,* 2008), provided

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that the correct pomace application technique is determined. Indeed, the mineralization of organic matter is enhanced when the pomace is distributed on the soil surface without incorporation (Proietti *et al.,* 2015).

As a soil amendment, olive pomace has already been used on agricultural soils (Roig *et al.,* 2006; Alburquerque *et al.,* 2007; Federici *et al.,* 2009). Indeed, it has been a widespread practice in olive groves in Italy for a long time, because, in addition to being economical and easily achievable, it has positive effects on soil characteristics and crops (Lozano-Garcia *et al.,* 2011; Toscano *et al.,* 2012). Another Italian study by Toscano and Montemurro in 2012, showed that olive pomace has a similar chemical composition to an organic soil amendment and can therefore be used for agronomic purposes.

The objective of this study is to value Moroccan olive pomace as a soil amendment, and to compare the agronomic value of pomace from the three extraction systems: the traditional system, the two-phase continuous system, and the three-phase continuous system.

Materials and Methods

Experimental design

The experiment consists in germinating the bean in pots with different percentages of olive pomace, from the three extraction systems, in order to see the influence of this pomace on the germination and evolution of the plant during its vital period. The test began with drying the pomace, grinding and sieving it to 1 mm before seeding (Table 1).

Each pot is irrigated with 300 mL of well water on the day of planting, and then the pots are irrigated regularly three times a week with 80 mL of well water for each.

Physico-chemical characterization of olive pomace

The pomace used in this study was collected from three crushing units: a traditional pressing system, based on manual extraction of oil from olive paste using pressing mats and natural separation of the oil from the olive mill wastewater by settling, and modern extraction systems (two phases and three phases) based on separation by centrifugation. The crushed olives originate from the city of Tahla (Tahla, Morocco, latitude 34°02’58’’ North, longitude 4°25’17’’ West, altitude above sea level: 606 m): a municipality in the province of Taza, in Fez-Meknès region.

The physico-chemical characteristics of the pomace from the three extraction systems are presented in Table 2 (Ameziane *et al.,* 2018).

Plant material: The bean

The Vicia fabae species is found in all regions of Morocco, this species includes several varieties including Aguadulce, used in this study: it is a local variety, sensitive to water shortage, it likes fresh, deep, and low acid soils (Alaoui, 2005). It is sensitive to compaction and excess water, it is rustic in the cold (Alaoui, 2005).

Physico-chemical analyses of soil and irrigation water

To carry out the physico-chemical characterization, a representative soil sample is sieved to 2 mm and then dried in an oven at 60 °C to determine the pH, electrical conductivity (EC), micro and macronutrients.

The moisture content is determined by drying the sample at 105 °C to constant weight. For organic matter, an oven-dried sample is burned at 525 °C for 3 hours. The pH and EC are measured in the aqueous extract using the ratio 2:5 (w/v) for pH and the ratio 1:5 (w/v) for EC (ISO 11265, 1994).

Total nitrogen is measured by the Kjeldahl method (Bremner *et al.,* 1982), total organic carbon by the Anne 1945 method (Bonneau *et al.,* 1994). Macro and microelements (P_2O_5, K_2O, Ca, Mg, Na, Ni, Fe, Cu, Mn, Zn, Cr) are determined by atomic absorption spectrometry at the Regional Centre for Agronomic Research in Rabat. The grain size is determined by Robinson pipette method (Nalovic *et al.,* 1968).

Irrigation water is also characterized by a set of physicochemical parameters, in order to meet Moroccan irrigation standards. The pH is measured using a 206 Lutron pH meter, conductivity with a

Table 1. Percentages of olive pomace used in the experiment

Percentage of olive pomace	0%	10%	15%	25%	50%	75%	100%
Percentage in soil	100%	90%	85%	75%	50%	25%	0%

Table 2. Physico-chemical parameters of the pomace from the three extraction systems

Physico-chemical parameters	Type of olive pomace		
	Olive pomace from the traditional pressing system (GT)	Olive pomace from the two-phase system (G2Ph)	Olive pomace from the three-phase system (G3Ph)
pH	6.04 ± 0.02	5.90 ± 0.02	5.94 ± 0.03
Electrical conductivity in ms/cm	2.62 ± 0.10	2.47 ± 0.09	3.21 ± 0.36
Moisture in %	43.33 ± 1.87	52.81 ± 0.77	53.56 ±1.63
Organic matter in %	77.02 ± 0.88	74.69 ± 13.36	92.03 ± 4.65
Total organic carbon %	49.72 ± 0.36	49.32 ± 0.36	50.79 ± 0.31
Total nitrogen in %	0.00257	0.00175	0.00402
Total Phosphorus %	0,00015	0.02	0.04
Calcium %	0.29	0.23	0.28
Potassium %	6.70	4.60	9.4
Magnesium %	0.04	0.03	0.03
Sodium %	0.9	1	1
Iron mg/kg	154	115	122
Copper mg/kg	19	8	9
Zinc mg/kg	100	74	104
Nikel mg/kg	13	5	6
Chromium mg/kg	22.40	5.80	24.50
Manganese mg/kg	7	5	6

WTW LF90 conductivity meter, turbidity with a 21009 HACH turbidimeter. Salinity by an ATC salinometer HI 9835. The concentration of nitrates, and ortho-phosphates by spectrophotometry. Chloride concentration by the Mohr method and sulphates by the nephelometric method. The analysis of calcium and magnesium used to determine the sodium absorption ratio (SAR) is determined by volumetric titration, while boron and sodium are determined by ICP-AES at the Scientific Research Technical Support Unit (UATRS) in Rabat.

Measured parameters

Regular monitoring of the bean plant is carried out. Three parameters were determined: height of aerial parts (stems), number of leaves, and leaf area. Immediately after harvest, the weight of the dry matter of the aerial parts (stems + leaves) was measured after drying for 72 hours in an oven at 60 °C. The leaf area is calculated by multiplying the length (L) by the width (l) of each leaf (Parcevaux *et al.*, 1970): $S = L * l$.

Statistical analysis

The experimental data were subjected to unidirectional analysis of variance (ANOVA) and mean separations were made by the smallest difference (LSD) at the significance level of $P<0.05$, using the Statgraphics centurion XVI program for Windows.

Results

Characterization of the raw material

Soil

The soil used in this study comes from the city "Salé" (Salé, Morocco, latitude 34°03'11'' North, longitude 6°47'54'' West, altitude above sea level: 34 m). It was sampled from the topsoil (0-20 cm deep) of a callistemon. This is a sandy type of soil with the following main properties (Table 3).

Irrigation water

The water used in this study for bean irrigation comes from a well at the city of "Salé" specifically "High School of Technology", whose physico-chemical characteristics are in compliance with the Moroccan standard for irrigation water (S.E.E.E, 2007):

Phenology of culture

The bean is sown at the beginning of February, using different percentages of olive pomace from the three extraction systems. The test lasted 4 months, then the leaves turn yellow and the plants start to lose their leaves.

The emergence of seedlings is almost identical for the seedlings sown in the different soil types (Table 5), and is compatible with the optimal day of appearance of the bean seedling (9th day) (ITCMI, 2010). As well as for the appearance of the first leaflet, it is similar for sprouted plants in different soil types (Table 5) and compatible with the optimal day of appearance of the first bean leaflet (11th day) (ITCMI, 2010). While the opening of the flowers of the first bunch was early for plants fertilized by pomace from three-phase system and traditional system, compared to plants amended by pomace from two-phase system and control plants (Table 5). This early flowering can be associated with the high concentration of potassium in pomace from traditional system (6.7%) and three-phase system (9.4%) compared to pomace from two-phase system (4.6%) and the soil (0.0445%), given the important role of potassium in accelerating flowering. Indeed, potassium helps the plant assimilate sugars and starches and it contributes to increasing energy reserves and the construction of complex carbohydrates that structure leaves, stems and flower buds.

Effect of pomace addition on bean growth

Stem size

The addition of pomace to the soil favourably influences the growth of the bean. Indeed, the stem size of the seeded plants in percentages of 10%, 15% to 25% is on average higher for pomace from two-phase system and traditional system than the stem size of the plants fertilized by pomace from three-phase system (Figure 1), but this size remains significantly identical compared to the control plants ($p>0.05$).

Table 3. Soil physico-chemical parameters

Physico-chemical parameters	Soil characteristics
Clay in %	9 ± 0.044
Sand in %	68 ± 0.088
Silt in %	23 ± 0.044
pH	7.61 ± 0.044
Electrical conductivity in µS/cm	85.5 ± 0.149
Moisture in %	4.51 ± 0.044
Organic matter in %	6.88 ± 0.125
Total organic carbon %	4.88 ± 0.333
Total nitrogen in %	0.134
Total Phosphorus %	0.0103
Calcium %	0.48
Potassium %	0.0445
Magnesium %	0.0243
Sodium %	0.0092
Iron mg/kg	221
Copper mg/kg	138
Zinc mg/kg	67
Nikel mg/kg	19
Chromium mg/kg	29.3
Manganese mg/kg	2

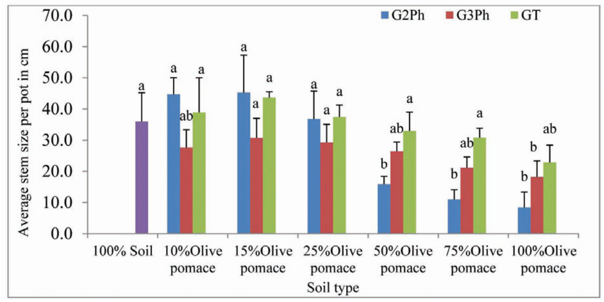

Fig. 1. Effects of different concentrations of olive pomace on the size of *Vicia fabae* stems (Values with different letters are significantly different: $p<0.05$)

Number of leaves

The number of leaves of plants fertilized by pomace from traditional system grows significantly ($p<0.05$) in pots with a pomace percentage of 10%, 15%, 25%, 50% and 75% compared to control plants (Figure 2), while the number of leaves of plants amended by pomace from two-phase system and three-phase system is significantly lower ($p<0.05$) compared to control plants.

The improvement in stem size and number of leaves observed when using olive pomace can be attributed to several factors. Indeed, the sandy soil of the EST has a pH close to basicity (7.61), while the pomace from the three extraction systems has a low acid pH (5.9 - 6.09), so the addition of pomace at low doses will reduce the soil base to ensure an optimal environment for solubilisation and assimilation of

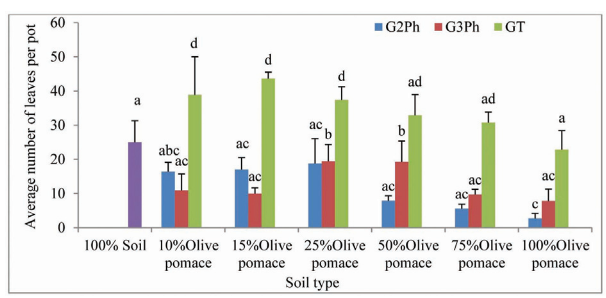

Fig. 2. Effects of different concentrations of olive pomace on the number of *Vicia fabae* leaves (Values with different letters are significantly different: $p<0.05$)

nutrients (Jinendra *et al.*, 2004) on one hand. On the other hand, the soil studied has a low concentration of organic matter and therefore a low percentage of total organic carbon, its total nitrogen content is moderate (0.134%), it is rich in calcium (0.48%) but low in phosphorus (0.0103%), potassium (0.0445%), magnesium (0.0243%) and sodium (0.0092%). But thanks to the richness of pomace in organic matter, the soil's capacity to retain water and nutrients increases (Chouinard *et al.*, 2000). Indeed, the richness of the pomace in calcium favours flocculation and the association of colloids to form the clay-humic complex, essentially negatively charged, which attracts the macroelements (K^+, Mg^{2+}, Na^+), which present 99% of the dry matter of the plant (UIF., 1988), contained in the pomace in order to enrich the poor soil of EST.

Leaf area

The leaf area of plants amended by the pomace from the traditional system and three-phase system remains on average smaller than the leaf area of the others plants, except for the pots fertilized by 75% pomace from three-phase system and 100% pomace from the traditional system. While the leaf area of plants fertilized by pomace from two-phase system occupies the first round, plants amended by 10%, 15%, 50% and 75% of pomace from the two-phase system have a larger average leaf area and significantly different ($p<0.05$) from the control plants. The variability of the leaf area is explained by the variability of the average number of leaves per plant, and the size of the leaflet in each pot.

These elements particularly concern the conformation of the vegetative system of the plants in each pot, which is a problem of nutrients, especially nitrogen (Cubaka Kabagale, 2010). Indeed, a nitrogen deficiency leads to narrow leaves, but in case of phosphorus deficiency, even with a high concentration of nitrogen, the latter gradually accumulates in the green part of the leaf, without causing an increase in the plant mass (Marchal, 1971). Therefore, in our case, even if the nitrogen concentration in the pomace from three extraction systems is negligible, the leaf area of the plants amended by the pomace from two-phase system is larger, since the phosphorus concentration in the latter is high (0.02%) compared to the concentration contained in the pomace from traditional system (0.00015%). Indeed, the bean and as for most plants has nodules that allow the fixation of atmospheric nitrogen when necessary, and therefore even with a low nitrogen concentration, it is phosphorus that influences the leaf surface, in fact it is a growth limiting factor, and it is in synergy with nitrogen and with many other elements (Marchal, 1971).

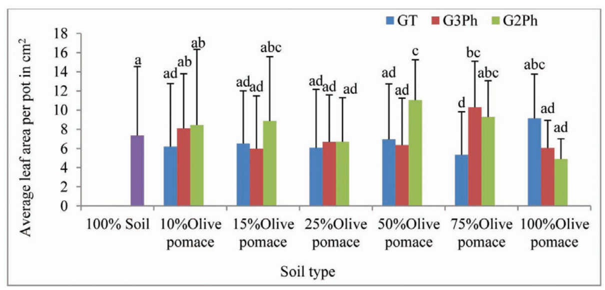

Fig. 3. Effects of different concentrations of olive pomace on the leaf surface of *Vicia fabae* (Values with different letters are significantly different: $p<0.05$)

Table 4. Physico-chemical parameters of irrigation water

Physico-chemical parameters	Characteristics of irrigation water
pH	7.49 ± 0.047
Electrical conductivity in ms/cm	1.024 ± 0.016
Temperature in °C	18.13 ± 0.058
Suspended matter e mg/L	0.232 ± 0.033
Salinity in ppb	0.3 ± 0.1
Nitrates in mg/L	7.04 ± 0.007
Chlorides in mg/L	192.5 ± 0.044
Boron in mg/L	0
Sulphates in mg/L	21.33 ± 0.005
Ortophosphates in mg/L	0.0134 ± 0.0001
The SAR	0.53 ± 0.5

Dry matter

The addition of pomace improves the dry matter weight of the bean feet (stems and leaves), compared to the control (Figure 4). The improvement is considerable for the 10% pomace concentration from traditional system ($p<0.05$), while it is not significantly different from the control ($p>0.05$) for 15% and 25% pomace concentrations from two-phase system. This improvement can be explained by the richness of these pomace, in macro-elements such as sodium, calcium, magnesium and potassium, which participate in the formation of plant tissues, and represent 99% of their masses (UIF, 1998).

Comparison of the agronomic value of the pomace from the three extraction systems

In terms of comparison between the pomace from

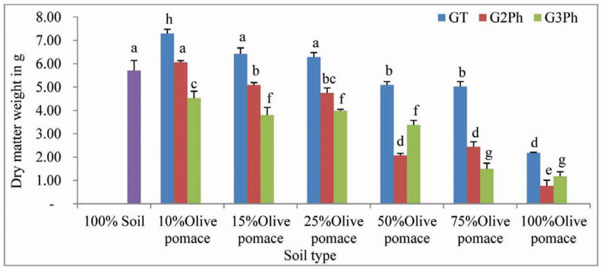

Fig. 4. Effects of different concentrations of olive pomace on the dry matter weight of *Vicia fabae* (values with different letters are significantly different: $p<0.05$)

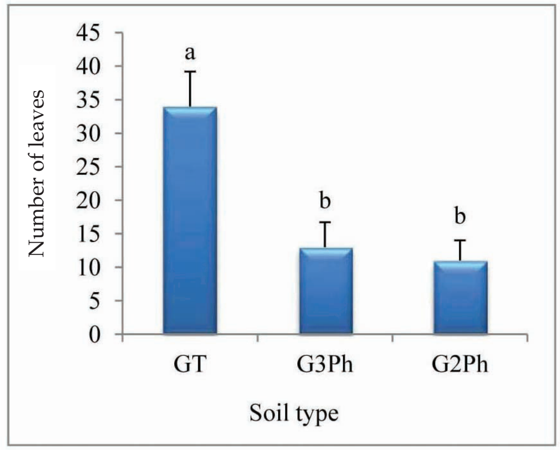

Fig. 6. Comparison of the average number of leaves of the bean for the different fertilizers

the three extraction systems, in order to use them as a soil amendment, it can be seen that the plants amended by the pomace from traditional system have a large stem size (Figure 5), with a large number of leaves (Figure 6), but a small leaf area (Figure 7) compared to the number of leaves. While plants fertilized by pomace from two-phase system, and three-phase system, have a moderate stem size, with a smaller number of leaves, compared to plants amended by pomace from traditional system, but these leaves have a large leaf area, and knowing that it is at the leaf level, where photosynthesis takes place, necessary for plant growth and development, it can be said that these pomace, (the pomace from

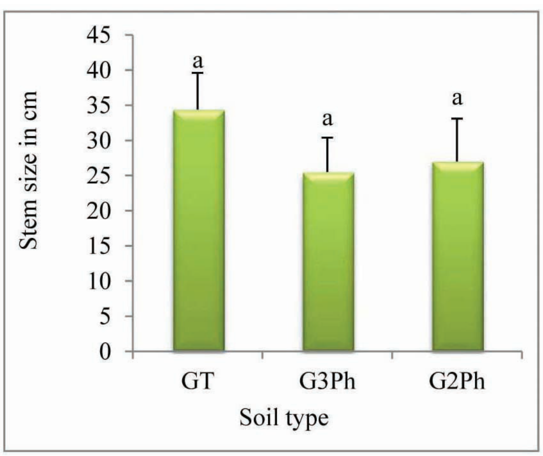

Fig. 5. Comparison of the average stem size of the bean for the different fertilizers

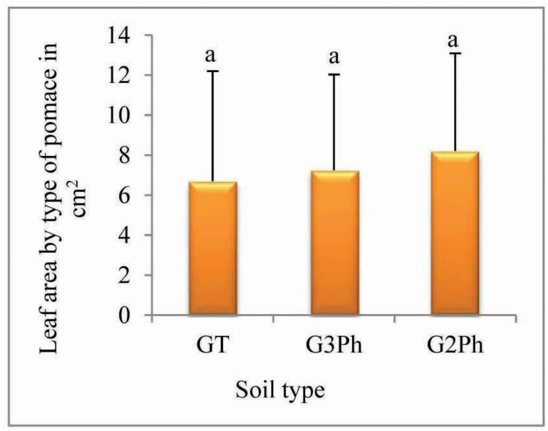

Fig. 7. Comparison of the average dry matter weight of the bean for the different fertilizers

two-phase system and three-phase system), have an important nutritional contribution for the plant.

In terms of dry matter, since the plants fertilized by the traditional system pomace have a large stem size, with a large number of leaves, their dry matter weight will be significant compared to the plants amended by the pomace from two-phase system and the three-phase system, but this difference is not significantly different ($P>5\%$), which always gives the pomace from the continuous system its special character.

Table 5. Phenology of bean cultivation for different soil types

Type of olive pomace	Traditional pressing system	Two-phase system	Three-phase system	Soil
Appearance of seedlings	9th day	10th day	8th day	9th day
Appearance of the first leaflet	12th day	12th day	11th day	11th day
Opening of the flowers of the first bunch	40th day	64th day	40th day	61th day

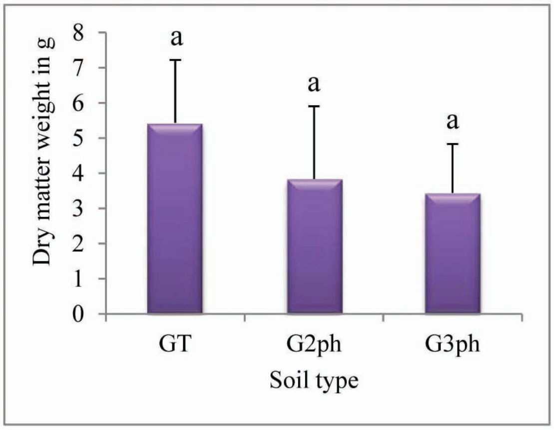

Fig. 8. Comparison of the average leaf area of bean leaves for the different fertilizers
(Values with different letters are significantly different: $p<0.05$)

Fructuration, pests and crop maintenance

In terms of yield, no fructuration is observed at the end of the plant period, this can be attributed to the absence of pollinating conditions, namely wind and insects, since the plants are germinated in the laboratory in order to control external conditions. Indeed, work carried out by Poulsen (1973) underlines the importance of bumblebees in bean pollination, and a study conducted by Free (1966) also judges the importance of bees in the pollination of male-sterile bean flowers. However, there are also growing conditions that prevent the plant from bearing fruit, namely, excess foliage that causes the crop's photosynthetic yield to fall as a result of heating or lowering the received light intensity (Soltner, 1978). This justifies the systematic leaf removal of bean plants in much denser leaf pots.

It has been noticed in the crop, the presence of grey rot on the bean leaves, which is a disease caused by several fungi of the family "Botrytis". A grey veil forms and causes infected areas to rot (ITCMI, 2010). This presence is involved in reducing the density of plants and leaves.

Affected plants were dug up and thrown out of the pots. Weeding has taken place whenever undesirable plants appear.

Discussion

Our results are comparable to those reported by other authors who have worked on other plants. Indeed, López-Piñeiro *et al.* (2006) in winter wheat crops grown in greenhouses in Spain, observed an increase in yields up to 198% following the amendment of wheat by olive pomace. Similarly, in an Italian study, Brunetti *et al.* (2005) found an increase in the production of Triticum turgidum L. related to grain mass, number of grains per square meter, and soil organic matter content after amendment by olive pomace (10 and 20 t/ha). Due to its high organic matter content, Tajada and Gonzalez (2004), found that the application of 10, 20, 30 and 40 t/ha of wet pomace to a two-year maize crop in Spain increased yield in the second experimental season, following the residual effect of the organic matter applied in the first season.

Another study conducted in Italy by Nasini *et al* (2013) showed an increase in shoot growth, volume and weight of the olive canopy fertilized by olive pomace (50 t/ha) after 4 years of amendment.

A positive effect on olive tree yield in Spain, following the increase in organic matter, total nitrogen and available phosphorus and potassium content, has also been demonstrated by López-Piñeiro et al (2008), due to the use of wet and de-oiled pomace as soil amendment.

Conclusion

The pomace studied have appreciable quantities of nitrogen and phosphorus nutrients, a large quantity of organic matter and a slightly acidic pH (6.04 to 5.9), which makes it possible to predict an improvement in the quality of the sandy soil of EST Salé. The metal contents of the pomace from the three extraction systems comply with the NFU 44-051 (2006) standard for organic amendments.

The pomace studied gives a better germination of bean seeds, than the soil of EST Salé, for concentrations of 10%, 15% to 25%. Indeed, the contribution of pomace improves all the growth parameters of the bean (number of leaves, stem sizes, leaf area and dry matter weight), to be related to the fertilizing power of pomace (N, K, P, etc.).

The comparison of the fertilizing power of the pomace from the three extraction systems shows that the pomace from two-phase system has a better nutrient supply for the plants, with an optimal stem size, a larger leaf area, and a high dry matter weight, compared to the soil, especially for a 10% pomace dose.

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