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Jatropha *curcas* sludge valorization

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Abstract

Jatropha which grows in tropical and subtropical climates across the developing world, is a perennial species that received much attention for its ability to grow on ‘marginal land and to produce seeds with high oil percentage. Among the different species of Jatropha, *Jatropha curcas* is suitable as ornamental plant, raw material for dye, potential feed stock, soil enrichment manure and more importantly for biodiesel production. The mechanical pressing of the Jatropha seeds for oil production results in large amounts of solid residue (seed cake) and sludge that contain oil, water, minerals, proteins, toxic compounds and anti-nutritional factors. The aim of our work was to screen the fertilizing power of Jatropha sludge and its oily and solid fractions for promoting biodiesel circular economy. Our results indicated that seeds of watercress had a better germination performance than lettuce with Jatropha sludge and its fractions. This could depend on the different sensitivity of the two species and/or also to the composition of the sludge and its fractions. The solid fraction had the greatest inhibitory effects on germination of both species. The oily fraction had the less phytotoxic effect on the germination process while only in presence of the total sludge at 25%, seeds of watercress and lettuce showed a germination percentage lower than 50%. Higher concentrations were completely inhibitory. The phytotoxic effects of the sludge and its fractions may be attributed to the combination of high EC and phenol contents. This study revealed that highly diluted Jatropha total sludge may be very useful as good source of nutrients for crop production, cutting short the use of chemical fertilizers.

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Keywords: Jatropha curcas; lettuce; seed germination; sludge; watercress.

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1. Introduction

Currently, due to the gradual depletion of world petroleum reserves and to the impact of the increasing exhaust emissions on the environment, there is an urgent need to develop alternative green energy resources, such as biodiesel fuel (Proto, Zimbalatti, Abenavoli, Bernardi & Benalia, 2014; Moneti, Delfanti, Marucci, Bedini, Gambella, Proto & Gallucci, 2015). Inedible vegetable oils, mostly produced by seed-bearing trees and shrubs can provide an alternative, with no competing food uses. Most of the crops grown today, including oilseeds, are annuals. Perennial crops have fewer environmental impact than annual crops. They have deeper root systems, which help store more carbon, maintain soil quality, and manage water and nutrients more conservatively. Perennial crops have therefore been advocated as potentially more efficient ways of farming, especially on marginal soils (Cox, Glover, Van Tassel & De Haan, 2006; Glover, Cox & Reganold, 2007). Jatropha which grows in tropical and subtropical climates across the developing world (Openshaw, 2000), is one perennial species that has received much attention recently for its ability to grow on ‘marginal land (Gubitz, Mittelbach & Trabi, 1999; Achten, Mathis, Verchot, singh, Aerts & Muys, 2007; Fairless, 2007). Among the different species of Jatropha, Jatropha *curcas* has a wide range of uses and promises various significant benefits to human and industry. This plant can be used as an ornamental plant, raw material for dye, potential feed stock, pesticide, soil enrichment manure and more importantly as an alternative for biodiesel production (Junfeng, Haixlna & Zhi, 2010). The mechanical pressing of the Jatropha seeds for oil production results in large amounts of solid residue (seed cake) used as pellet, and of sludge that contains oil, water, minerals, proteins and also toxic compounds and anti-nutritional factors (McKendry, 2002; Openshaw, 2000; Manurung, Wever, Wildschut, Venderbosch, Hidayat, Van Dam, Leijenhorst, Broekhuis & Heeres, 2009). The use of this sludge is very important for reducing the potential environmental damage caused by the improper disposal of this by-product. Hence, an attempt was made to chemically characterize the total sludge and its fractions and to test their phytotoxicity on germination and growth of crop species. The aim was to evaluate the possibility of using these by-products as fertilizers for promoting the circular economy.

2. Methods

2.1. Extraction process

The extraction process was conducted at the Environmental Technology Park "Ecolandia", situated in Arghillà, in the municipality of Reggio Calabria. Four different temperatures, starting from 95 ° C and going up at intervals of 15 ° C up to a maximum of 140 ° C were used. All the tests were carried out both with seed and with shelled seed. The machine used was a continues pressing for oilseeds, OLEO model 20, built in 2015, adapted to extract crude vegetable oil by continuous mechanical pressing without the use of solvents. For each test cycle the machine was undergone to 20 minutes of initialization to reach the operating parameters. Such machinery is able to directly expel a pelleted protein residue. The first step of pretreatment involved the separation of the oil from the sludge within a vertical gravity decanter, in which the oil came pushed by a pump suction timed, and it remained here for a minimum of 100 hours. The sludge was subsequently decanted, through a process of spontaneous sedimentation, which resulted in a solid residue and in an oily phase. Chemical parameters of the three fractions (as such, oil and solid residue) were determined in three replicates as follow: pH was measured in distilled water using a 1:2.5 (residue/water) suspension; organic carbon was determined by the Walkley–Black procedure (Nelson & Sommers 1982), and it was converted to organic matter by multiplying the percentage of carbon by 1.72; total nitrogen was measured by Kjeldahl method (Bremner & Mulvaney 1982); electric conductibility was determined in distilled water by using 1:5 residue: water suspension, mechanically shaken at 15 rpm for 1 hour to dissolve soluble salts, and then detected by Hanna instrument conductivity meter; total water-soluble phenols were measured by using the Folin–Ciocalteau reagent, following the Box method (1983). Tannic acid was used as a standard and the concentration of water-soluble phenols was expressed as tannic acid equivalents.

2.2. Phytotoxicity test

Germination test was conducted in vitro by evaluating the germination and early growth of two plant species (watercress and lettuce). Seeds of watercress (*Lepidium sativum L.)* and lettuce (*Lactuca sativa* L. var. *Longifolia*), in number of 20, were placed in Petri dishes (9 cm diameter) containing filter paper soaked with 5 mL of each fraction. Different concentrations were used and distilled water was the control. In particular, the following four concentrations were tested: 25%, 50%, 75% and 100%. The tests were conducted in triplicate for each dose, for each matrices mentioned above, and for each plant species. The plates were placed inside a climatic cell (Growth Chamber System, GC-300), for 10 days, through daily monitoring was examined germination and growth of the seedlings.

3. Results

3.1. Chemical characteristic of sludge and its fractions

Chemical characteristics of sludge as such, and its solid and oily fractions are showed in table 1. From analyzes carried out, it appears that, sludge obtained from the pressing of the seeds of Jatropha *curcas*, and oil were neuter, except for the solid residue whose pH was moderately acid. The highest value of electrical conductivity was detected in the solid residue, while the oil presented significantly lower values. Phenol content was high in all matrices assayed, but among them the lowest value was encountered in the oily fraction. The values of organic carbon and organic matter were elevated and the amount was in the ranking Sludge>solid residue>oil. The amount of nitrogen was low in all the three matrices analyzed.

Table 1. Chemical characteristics of sludge as such and its fractions. pH, Electric conductivity (E.C.), Phenols, Organic Carbon (O.C.), Organic Matter (O.M.), Total Nitrogen (N).

Matrices	pH	E.C. (dS/m)	Phenols (mg TAE L^{-1})	O.C. (g Kg^{-1})	O.M. %	N %
Sludge	7.20^{a*}	3.63^{b}	2675^{a}	819^{a}	143	0.021
Solid residue	5.98^{b}	5.52^{a}	2091^{b}	802^{b}	137	0.030
Oil	6.80^{a}	0.6546^{c}	1100^{c}	715^{c}	124	0.070

*Means with the same letter are not significantly different (Tukey's test, $p \leq 0.05$)

3.2. Germination test

Phytotoxicity tests showed that, when sludge and its fractions were used as such (100%) germination of both species, watercress and lettuce was completely inhibited. The solid residue inhibited watercress germination at all concentrations used. The total sludge, was phytotoxic at a concentration of 75 and 50% (Fig. 1). Watercress germination (50% of seeds) occurred only if it was diluted at 25% (Fig 1.). The germination percentage was different between the two species. Only 22% of lettuce seeds germinated in presence of 25% of total sludge. Lettuce germination was inhibited by the oily fraction, at the concentration of 75 % (Fig. 2), conversely, watercress still had a high germination percentage (80%) (Fig. 1.). However, the oily fraction, in any case slowed down the germination of watercress and lettuce in respect to the respective controls. Only when the oily fraction was used at 25%, the germination of lettuce and watercress was 100% and the growth of the two species was comparable to the control.

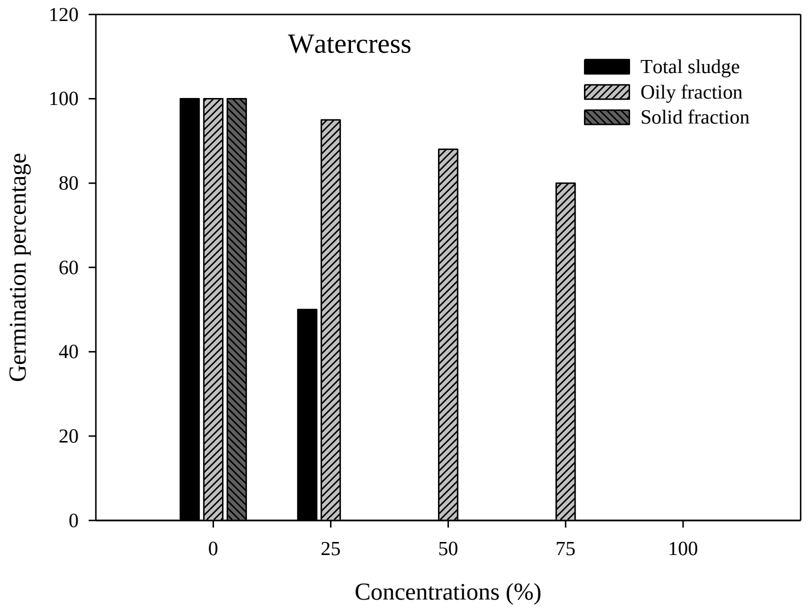

Fig. 1. Germination percentage of watercress in presence of different concentrations (100%, 75%, 50% and 25%) of Jatropha curcas sludge used as such, oily and solid fractions.

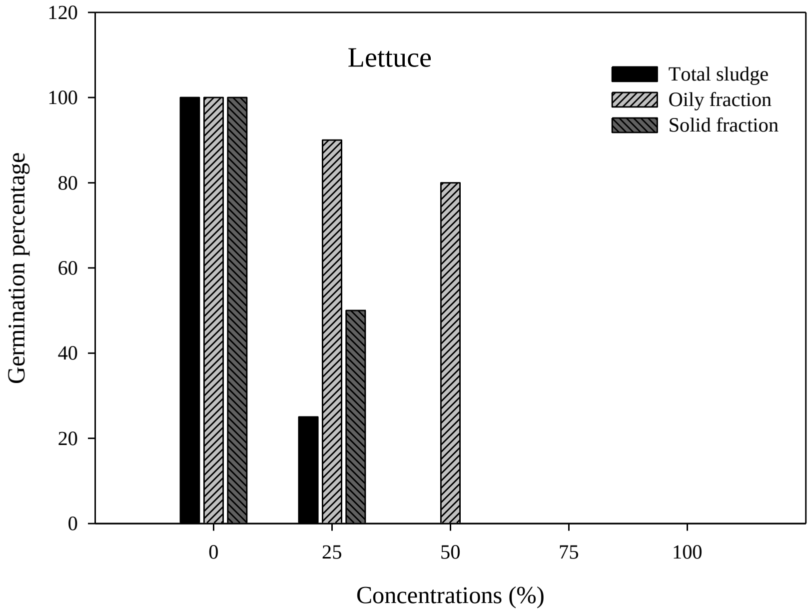

Fig. 2. Seed germination percentage of lettuce in presence of different concentrations (100%, 75%, 50% and 25%) of Jatropha *curcas* sludge used as such, oily and solid fractions.

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4. Discussion

Seed germination test is one of the simplest method of environmental biomonitoring (Wang 1990; Wang & Keturi, 1990). This method was developed to ascertain the toxicity of polluted liquid samples, or of extracts from solid matrices on seed germination (Araùjo, Sahyoun & Monteiro, 2001; Araújo & Monteiro, 2005). Our results indicated that seeds of watercress had a better performance than lettuce during germination period in presence of jatropha sludge and its fractions. This could depend on the different sensitivity of the two species and/or also to the differences in the composition of the sludge and its diverse fractions. The greater inhibitory effects of the solid fraction from sludge may be attributed to the combination of high EC and phenol contents. EC values were considerably high in the solid residue and a bit less high in the total sludge. The solid residue was phytotoxic at all concentrations used.

The oily fraction, with a lower amount of salts and phenols with respect to the sludge as such and to the solid fraction, showed the least inhibitory effect on seed germination.

The solid residue constitutes the 40% of the total sludge. This may explain the phytotoxic effect of sludge as such when used at the concentrations higher than 25%. The high oil content in the total sludge (more than 60%), contributed to low the electric conductivity, allowing the seeds of lettuce and watercress to germinate when the total sludge was used at the lowest concentration (25%). Many works were addressed on testing the fertilizing effects of Jatropha seeds cake to closing the productive loop utilizing this byproducts. The novelty of our study was that of using the sludge, never used before, as fertilizer, for taking *economic and environmental advantages* from the whole Jatropha chain. In short, these results indicate that the sludge obtained from the mechanic pressing of Jatropha *curcas* seeds, could be used as fertilizers but at very low percentage. Additionally a specie-specifity is emerged, meaning that, before amending the soils with this kind of sludge, an in vitro germination test is needed to individuate the crop that better adapt to germinate and grow in presence of Jatropha sludge, and the best amount to be used. In conclusion, we can suppose that the establishment of Jatropha plantations on degraded land will not only lead to carbon sequestration in soil and standing biomass, it will also reduce soil erosion helping to improve soil quality. Additionally the use of seed mechanic pressing by-product as fertilizer can contribute to the recovery of exhausted agriculture soils.

5. Conclusion

This study revealed that highly diluted Jatropha total sludge may be very useful as good source of nutrients for crop production, cutting short the use of chemical fertilizers. This could represent a very effective waste recycle and nutrient management strategy to meet both food and energy needs.

Acknowledgements

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