Journal of Environmental Management 180 (2016) 180–189

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Vermicomposting transforms allelopathic parthenium into a benign organic fertilizer

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ARTICLE INFO

Article history:
Received 24 June 2015
Received in revised form
2 April 2016
Accepted 3 May 2016

Keywords:
Parthenium hysterophorus
Allelopathy
Vermicompost
Seed germination
FT-IR

ABSTRACT

Vermicompost, which had been derived solely by the action of the epigeic earthworm *Eisenia fetida* on parthenium *(Parthenium hysterophorus)*, was tested for its impact on the germination and early growth of green gram *(Vigna radiata)*, ladies finger (*Abelmoschus esculentus)* and cucumber *(Cucumis sativus)*. Seedlings were germinated and grown in soil amended with 0 (control), 0.75, 1.5, 2, 4, 8, 20 and 40% (by weight) parthenium vermicompost. Even though parthenium is known to possess strong negative allelopathy, as also plant/animal toxicity in other forms, its vermicompost (VC) manifested none of these attributes. Rather the VC enhanced germination success, introduced plant-friendly physical features in the container media, increased biomass carbon, and was seen to promote early growth as reflected in several morphological and biochemical characteristics in plants which had received parthenium VC in comparison to those which had not. All these effects were statistically significant. Fourier Transform Infrared (FTIR) Spectrometry revealed that the phenols and the sesquiterpene lactones that are responsible for the negative allelopathic impact of parthenium were largely destroyed in the course of vermicomposting. FTIR spectra also indicated that lignin content of parthenium was reduced during its vermicomposting. The findings open up the possibility that several other invasives known for their negative allelopathy and toxicity may also produce vermicompost which may be plant-friendly and soil-friendly. It also makes it appear possible that the huge quantities of phytomass that is generated annually by parthenium can be gainfully utilized in producing organic fertilizer via vermicomposting, thereby providing a means of exercising some control over parthenium's rampant growth and invasion.

1. Introduction

Parthenium *(Parthenium hysterophorus)* is one of the most aggressively colonizing and ecologically harmful of terrestrial weeds (Adkins and Shabbir, 2014; Tanveer et al., 2015; Kaur and Aggarwal, 2016 Safdar et al., 2016). It has invaded most countries in the tropical and sub-tropical world, causing massive losses in agricultural production. In just one province (Queensland) of a single country (Australia), direct and indirect losses caused by parthenium are estimated to exceed 100 million Australian dollars per year (Adamson and Bray, 1999). Each mature parthenium plant can generate as many as 150,000 seeds (Dhileepan, 2012), which are dispersed by wind, water, animals, motors, fodder, etc (Mainali et al., 2015). The seeds have high survival rate and they achieve equally high germination success. These attributes along with fast growth rate make parthenium a rampant colonizer of parks, pastures, orchards, croplands, road-sides, and other fragments of open land (Wiesner et al., 2007; Nigatu et al., 2010; Javaid and Riaz, 2012; Shabbir et al., 2015). It monopolises the use of space and nutrients in the habitat it invades, elbowing out other plants (Veeraputhiran, 2013; Qureshi et al., 2014; Khaket et al., 2015) thereby causing serious jeopardy to biodiversity and ecosystem services. Parthenium's colonization is fostered by the presence in it of sesquiterpene lactones, and phenolics – especially parthenin, coronopilin, hysterin, ambrosin, ferulic acid and anicic acid–which are toxic to other species of plants, and impart strong allelopathy to the weed (Reinhardt et al., 2009; Kaur et al., 2014; Kumar, 2015). A parthenium invasion soon eliminates most other species of plants, thereby destroying the habitat of animals depending on those plants (Tanveer et al., 2015). To make matters worse parthenium

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http://dx.doi.org/10.1016/j.jenvman.2016.05.013
0301-4797/

plays host to a number of crop pests (Sharman et al., 2009), and human disease vectors (Akter and Zuberi, 2009; Nguyen et al., 2010; Knox et al., 2011; Nyasembe et al., 2015).

Attempts to thwart parthenium spread by mechanical, chemical or biological means have proved ineffective as parthenium continues to spread, even threatening to overrun natural forests (Manoj, 2014; Hussain, 2016). Equally futile have been the attempts to find ways for gainfully utilizing parthenium. Even though a large number of options have been explored — for making parthenium a source of biopesticides (Datta and Saxena, 2001; Sreekanth, 2013; Kaur et al., 2016), green manure (Kishor et al., 2010; Kumar et al., 2012), energy (Patel, 2011; Singh and Garg, 2014; Tavva et al., 2016), essential oils (Miranda et al., 2016); drugs (Kumar et al., 2014a,b; Anwar et al., 2015; Singh and Beck, 2006), and nanoparticles (Abbasi et al., 2015a,b) — none of the methods has had economic viability. As a result, billions of tonnes of parthenium biomass that is generated annually across the world, remains unutilized. Besides causing other jeopardies mentioned above, it contributes to global warming as the debris and the dead plants of parthenium degrade aerobically/anaerobically in the open, releasing CO_2 and CH_4 (Abbasi and Abbasi, 2010; Abbasi et al., 2012a,b).

One of the ways by which biomass or similar other biodegradable substrates can be gainfully utilized as also have a substrate most of its carbon content sequestered is vermicomposting (Abbasi and Ramasamy, 2001; Abbasi et al., 2013; Hussain et al., 2016a). Vermicomposting is known to convert the substrate's nutrients into more bioavailable forms and imparts to it microflora that is beneficial for plants (Gomes-Brandon and Dominguez, 2013; Karthikeyan et al., 2014). As a substrate passes through the earthworm gut, it also acquires enzymes and hormones which are believed to stimulate seed germination (Atiyeh et al., 2000; Zaller, 2007; Lazcano et al., 2010), plant growth (Edwards et al., 2004; Lazcano et al., 2009; Samrot et al., 2015), yield and quality of fruits (Singh et al., 2008; Doan et al., 2015) and resistance to pests (Yardim et al., 2006; Edwards et al., 2010; Serfoji et al., 2010; Carr and Nelson, 2014). But using parthenium as a source of vermicompost has been besieged with two major problems:

a) Conventional vermicomposting technology has been commercially successful only when animal manure is the substrate. To a much more limited extent food waste has been vermicomposted. But no past attempts in vermicomposting phytomass by conventional vermireactors has shown the potential of large-scale utilization (Nayeem-Shah, 2014; Abbasi et al., 2015a,b). The necessity to pre-compost the phytomass and blend it with animal manure in the reported processes makes those processes inefficient and uneconomical. In particular, the requirement of animal manure in quantities comparable or higher than the quantities of phytomass-to-be-processed severely limits the viability of the reported methods. This is due to the fact that animal manure is a prized commodity with several competing uses and can not be found in quantities comparable to the phytomass quantities that need processing (Nayeem-Shah et al., 2013, 2015).
b) It is likely that parthenium vermicompost may also be toxic to soil/plants as parthenium is.

The first of these problems has been recently solved (Abbasi et al., 2015a,b), as studies at the corresponding author's laboratories have led to the development of the concept of high-rate vermicomposting and associated technology by which phytomass can be vermicomposted rapidly at a large scale without any precomposting or manure supplementation (Gajalakshmi et al., 2002, 2005; Abbasi et al., 2009, 2011; Tauseef et al., 2013, 2014). Novel continuously operable vermireactor systems have also been designed and patented to make way for large-scale vermicomposting of phytomass (Tauseef et al., 2013). The present work has aimed to assess the second problem.

2. Experimental

2.1. Germination and early growth

In separate treatments, each in triplicate, 60 randomly picked seeds of green gram (*Vigna radiata*), ladies finger (*Abelmoschus esculentus*), or cucumber (*Cucumis sativus*) were sown in plastic trays (36 cm b × 42 cm l × 10 cm h) containing soil amended with 0% (control), 0.75%, 1.5%, 2%, 4%, 8%, 20% and 40% (by weight) parthenium vermicompost. All sets were placed in identical ambient conditions, with dawn-to-dusk temperature 32 ± 3 °C; dusk-to-dawn temperature 27 ± 2 °C; and relative humidity 55 ± 15%. All the containers were watered and exposed to sunlight for 9–10 h per day. Germination was reckoned to have been successful when the seeds exhibited radial extension of ≥3 mm.

Three weeks after germination, the plants were harvested for the determination of their shoot length, root length, shoot fresh weight and root fresh weight. Known quantities of plant material were oven dried at 105 °C to a constant weight, to calculate their dry weight.

2.2. Analysis

After harvesting the plants, the container media (soil with or without added vermicompost) from each experimental container was sampled with a uniform cylinder of known internal diameter and height. After the volume of the samples had been measured, the samples were oven dried to constant weights at 105 °C. Bulk density, particle density, and total porosity were then determined by the procedures described by Carter and Gregorich (2006).

The water holding capacity of the vermicast was measured by filling the vermicast in cylinders with a pierced base. The cylinders were capped, immersed in water, and drained. They were weighed and then oven dried at 105 °C to constant weights. The loss of weight on oven drying gave the quantity of water held by the vermicast in each cylinder (Margesin and Schinner, 2005).

The analysis of chlorophyll, carotene and tissue nitrogen content was performed following standard methods (AOAC, 2012), using an Elico SL 164 UV-VIS spectrophotometer. The concentrations of ammonical nitrogen and nitrate in soil were determined by modified indophenol blue method (Bashour and Sayegh, 2007) and Devarda alloy method (Jones, 2001), respectively. For assessing microbial biomass carbon, which is an indicator of the quantity of living microbial biomass present in a soil (Jenkinson, 1988; Smith and Paul, 1990), the procedure of fumigation extraction as detailed by Margesin and Schinner (2005), was employed. To ensure that matrix effects do not influence the accuracy of the analysis, calibration curves were drawn by standard addition method and all analysis was repeated till concordant results were achieved.

For Fourier-transform infrared (FTIR) spectral studies, samples were oven dried, finely ground, mixed thoroughly with KBr (spectroscopic grade), homogenized in an agate mortar, and pelletized at a pressure of about 1 MPa. The spectra were recorded over 4000–400 cm^{-1} range at a frequency of 0.5 cm/s on a Nicolet iS50 FT-IR spectrometer.

The extent of significance in the observed variations was statistically determined by one-way repeated measure analysis of variance (ANOVA), multivariate analysis of variance (MANOVA), and least significant difference (LSD) —as per standardized