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THE IMPORTANCE OF EARTHWORMS IN SUSTAINABLE AGRICULTURE - documentary study

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Abstract: Sustainable development should balance the tremendous challenge of feeding a growing world population with the need for minimal environmental impact of agricultural production. Soils are essential to food production and agriculture is a key driver of global soil erosion and degradation. Earthworms act in soil in a number of ways that provide many ecosystem services that favor agro-ecosystem sustainability. The present review briefly describe the multiple benefits of earthworms activity in agricultural soil which help improve farm productivity and also evaluates the use of vermicompost in agriculture as an example of environmentally friendly, economically viable and sustainable management alternatives that protect and enhance the earthworm populations in soil.

Key words: *sustainable agriculture, soil fauna, earthworm, vermicompost*

INTRODUCTION

The global human population growth with the current estimate of around 9.7 billion people who will exist by 2050 (United Nations, Department of Economic and Social Affairs, Population Division, 2019) translates to an increased pressure and food demand, not only in term of quantity but also on the expected dietary value. As a consequence, globally agriculture will need to produce 70 percent more food in the same period, and sustainable food production systems are necessary to be implemented (FAO, 2009; 2016).

Sustainable agriculture is a concept that was defined in different ways, according with FAO (1989, 2014) translated in practice means “halting natural resource depletion and destruction, and promoting the maintenance of ecologically sound increases in agricultural productivity”. In his Ph.D. thesis, "Strategies for overcoming the barriers to the transition to sustainable agriculture", MacRae (1990) showed that the concept of agricultural sustainability is not new to science, farming practices or agricultural policy since have been a part of theory and practice in English agriculture for several hundred years until the mid-19th century. During the “green revolution” period, an extensive quantity of chemical pesticides and fertilizers were used to increase the crop yield from agricultural land but, in turn, the quality of the soil has reduced (Gupta et al., 2014; Vanita et al., 2014; Singh, 2018) and have increased the social and environmental risks. Soils are essential to food production and agriculture is a key driver of global soil erosion and degradation. A recent review of Kopittke et al. (2019) examined the importance of the ecosystem services provided by soils and raised the attention about the fact that intensification of agricultural production has already degrading soils unsustainably.

Earthworms are a major component of soil macro-invertebrate communities and act in soil in a number of ways that provide many ecosystem services that favour agro-ecosystem sustainability (Singh, 2018; Lavelle, 2016). Their role in soil formation and soil fertility have been first acknowledged by Darvin (1881) and latter recognized by many authors (Edwards & Bohlen, 1995; Kale, 1998; Lalitha et al., 2000). The abundance of earthworms in an agricultural field is influenced by the type of management practices, especially the intensity of soil disturbance generated by tillage, the quantity and quality of food sources, the structure of the soil, the soil bio-chemical environment, the climate and the soil microclimate.

The present review briefly describes the multiple benefits of earthworm's activity in agricultural soil which help improve farm productivity. It also evaluate the available literature and Internet resources on the use of vermitechnology in agriculture as an example of environmentally friendly, economically viable and sustainable management alternatives that protect and enhance the earthworm populations in soil.

Benefits of earthworm's activity in agricultural soil. Earthworms represent a major component of soil biota that provide a great variety of ecosystem services (Barrios, 2007; Wall, 2012; Blouin et al., 2013, Lavelle et al., 2016) and their influence on soil processes and plant growth has been extensively documented. They promote litter decomposition, accelerate the mineralization as well as the turnover of soil organic matter and water infiltration (Baker, 2007), and therefore profoundly affect soil properties (Hättenschwiler & Gasser, 2005). As a result of their feeding and burrowing habits, fragmenting and mixing of different soil components, production of castings and converting organic matter into soil humus, earthworms influence nutrient cycling processes in terrestrial ecosystems significantly (Edwards & Bohlen, 1995; Blouin et al., 2013). Earthworms concentrate the organic and mineral constituents in the food they ingest, so their casts are richer in available nutrients than the soil around them, process associated with an enrichment in labile compounds and with a subsequent increase in microbial activity (Coq et al., 2007; Abail et al., 2017). This way, large quantities of nitrogen and other macro-nutrients as P, K, and Ca in fresh cast depositions are easily assimilable by plants. Also, earthworms aerate the soil and improve soil drainage. Earthworms cast cement soil particles together in stable aggregates that store moisture without dispersing, so rain filtered through their burrows gives rise to worm-worked humus that can stores up to 40% more moisture to sustain crops through drought (go.nature.com/2oofvfq). Review of Chan (2001) emphasis that earthworms population of no-till agricultural systems were greater than conventionally tilled systems. In no-till soil system where earthworm populations are high, these channels may occur in such numbers as to contribute significantly to soil hydraulic conductivity and aeration status (Snyder & Vázquez, 2005). The increase in infiltration rate related to can decrease soil erosion by 50% (Shuster et al., 2000). The biostructures produced by earthworm influence soil physical properties and also plant growth. Scheu (2003) found that in 79% of 67 studies the shoot biomass of plants significantly increased in the presence of earthworms. An indirect impact of earthworms on primary productivity is through the use of vermicompost that shows a greater positive effect on plant growth than other compost (Phuong et al., 2011; Arancon & Edwards, 2011). The next part of present mini-review is dedicated to the literature that highlights the influence of the application of vermicompost in agriculture.

The use of vermitechnology and vermicompost in agriculture. Ismail (2005) defined vermitechnology as the use of local species of earthworm in composting and soil management. Chattopadhyay (2017) considers vermitechnology as a combination of vermiculture and vermicomposting being a process of composting organic wastes into valuable organic fertilizer by the action of earthworms. Vermiculture consist on the mass-rearing of special types of earthworms, which involves multiplication of earthworms stock by providing optimum environmental conditions such as proper moisture, temperature and food. Vermicomposting is the biological degradation and stabilization of the organic waste through the interaction between earthworms and microorganisms.

Example of use in cereal crops. Glasshouse studies made at CSIRO Australia on wheat plants grown in a “red-brown earth” with poor nutritional status and 60% moisture, with or without addition of earthworms, found that the earthworms *Aporrectodea trapezoids* increased growth of wheat (*Triticum aestivum*) crops by 39%, grain yield by 35%, lifted nitrogen value of the grain by 14% and crop resilience to diseases as compared to the control (Baker et al., 1997; Baker, 2007).

Mahmoud and Ibrahim (2012) confirmed the ability of vermicompost to improve the salinesodic soils. In case when the soil was treated with mixtures of vermicompost and water treatment residuals (WTR) this treatment exhibited the highest reduction in salinity, sodicity and soluble Cl^- and Na+. They showed that, consequently, the grain weight of barley has increased and the application of 10g kg^{-1} soil at 2:1 (Vermicompost: WTR) mixed ratio resulted in the best barley growth.

Mahmud et al. (2016) compared the application of vermicompost and chemical fertilizer on cereals and found a significantly influence of vermicompost in N, P, K and S content in grain and straw.

Vermicompost increases the soil nutrient content, promotes plant growth and chlorophyll production and boosts the overall maize growth (Gopal et al., 2010; Manyuchi et al., 2013). Biri et al. (2016) found that the application of vermicompost also enhanced the soil organic matter, total nitrogen and mineral nutrient content. They concluded that application of 1.0 t/ha vermicompost and 46 kg N/ha resulted in the best results in terms of enhanced soil chemical properties for plant growth as well as for the reduction of striga (*Tyto alba*) incidence and sustainable sorghum production.

Replacement of 25% of the nutrients provided to the corn plants by vermicompost maintains plant productivity at the same levels than 100% inorganic fertilization. In addition, vermicompost produces significant changes in soil biochemical and microbial properties promoting bacterial growth and increasing enzyme activity (Lazcano & Domínguez, 2011). Vermicompost application at a rate of 2.5 t/ha increased grain and straw yield of rice significantly and saved up to 50% of recommended NPK fertilizer rates in rice (Angadi & Radder, 1996).

Example of use in vegetable crops. Munroe (2007) reported that lettuce grown on vermicompost showed significantly higher yield by 20% in wet weight as compared to control and conventional compost. Average weight of lettuce head was 313g on vermicompost, while on ordinary compost it was 257.5g and 259.1 on control. The author also studied the agronomic impacts of vermicompost on tomato (*Lycopersicum esculentum*) crops and reported that the plants in vermicompost treatment were bigger and healthier and the yield was substantially higher compared to the other tomato plants without vermicompost or receiving a chemical optimal nutrient supply.

Ansari (2008) studied the production of potato (*Solanum tuberosum*), spinach (*Spinacia oleracea*) and turnip (*Brassica campestris*) in case of application of vermicompost in a reclaimed sodic soil in India. The overall productivity of vegetable crops during the two years of trial was significantly greater in plots treated with vermicompost applied at a rate of 6 t/ha as compared to control. There was significant improvement in soil quality of plots amended with at a rate of 6 t/ha vermicompost respectively: reduction from initial 96.74 to 73.68 in sodicity and increase from initial 336.00 kg/ha to 829.33 kg / ha in available nitrogen contents.

Suthar (2009) studied the impact of vermicompost, classical chemical fertilizers (NPK) and farmyard manure on root and shoot length, weight and number of cloves in garlic (*Allium sativum*) and found that the best growth performance was achieved on vermicompost applied at a rate of 15 ton/ha + 50% of recommended NPK rate. The average fruit weight on vermicompost treatment was also approximately 26.4% greater than the other combinations.

Karmegam and Daniel (2008) investigated the effect of vermicompost and chemical fertilizer on hyacinth beans (*Lablab purpureus*) and found that all growth and yield parameters respectively: total chlorophyll contents in leaves, dry matter production, flower appearance, length of fruits and fruits per plant, dry weight of 100 seeds, yield per plot and yield per hectare were significantly higher in those plots which received vermicompost either alone or in combination with chemical fertilizers. The highest fruit yield of 109 t/ha was recorded in plots that received vermicompost at a rate of 2.5 t/ha plus half dose of recommended NPK fertilizer.

Other studies comparing the impact of live earthworms, earthworm's vermicompost, cattle manures and chemical fertiliser on the growth and yield of important vegetable crops like tomato (*Lycopersicum esculentum*), eggplant (*Solanum melongena*) and okra (*Abelmoschus esculentus*) demonstrated very good yield results of vermicompost as fertilizer (Gutiérrez et al., 2007; Agarwal et al., 2010). The study of Meena et al. (2007) showed the positive impact of organic manure on garden pea (*Pisum sativum*) as compared with chemical fertilisers. Organic manure induced higher green pod plants, higher green grain weight per plant, higher percentage of protein content and carbohydrates and higher green pod yield as compared to chemical fertilizer.

Jeyabal & Kuppuswami (2001) showed how the judicious integration of 50% N through vermicompost, 50% N through fertilizer and biofertilizers, *Azospirillum* and phosphobacteria, each at 2 kg ha^{-1} can help achieving the desired increase in yields of the rice–legume cropping sequence.

On potato crop, the use of peat and vermicompost contributed to Mg uptake, vermicompost extract increased S concentration, while spraying with vermicompost extract contributed to N and P accumulation. In this investigation 50% of cases showed a reduction of Ca content in potato tubers, mainly in the treatments using foliar spray (Vojevoda et al., 2017).

In another study on vegetables amended with vermicompost and vermicompost extract showed that the yield of spinach and onion were significantly higher in plots treated with extract of vermicompost, the average weight of onion bulb was significantly greater in plots amended with vermicompost and vermicompost extract, the yield of potato and the average weight of potato tubers were significantly higher in plots treated with vermicompost (Ansari, 2008).

Example of use in fruit growing and viticulture. Various studies highlighted the positive influence of the application of vermicompost in vineyards. Adhikary (2012) showed in his paper that worm vermicompost boosted grape yield by two-fold as compared to chemical fertilizers treatment. Treated vines with vermicompost produced 23% more grapes and 18% increase in bunch numbers. Also, the yield in grapes can worth additional value (Buckerfield et al., 1998). Soil analysis in another study with vermicompost application in vineyards revealed that within one year pH came down from 8.3 to 6.9 and the value of potash increased from 62.5 kg/ha to 800 kg/ha. There was also found a marked improvement in the nutritional quality of the grape fruits (Sinha et al., 2009).

Singh et al. (2008) found that after the application of vermicompost on strawberries the yield increased by 32.7% and drastically reduced the incidence of physiological disorders like albinism (from 16.1% to 4.5%), fruit malformations (from 11.5% to 4%) and grey mould (from 10.4% to 2.1%). By suppressing the nutrient related disorders, the vermicompost increased the yield and quality of marketable strawberry fruits up to 58.6%.

Another study comparing the impacts on strawberries plants of amendment as vermicompost, at a rate of 10 tons/ha, and 85:155:125 kg/ha N: P: K fertilizers, when applied separately and in combination, showed that the yield of marketable strawberries and the weight of the largest fruit was significantly greater on plants grown on vermicompost as compared to inorganic fertilizers in 220 days after transplanting. There were 36% more "runners" and 40% more "flowers" on plants grown on vermicompost. Also, farm soils with vermicompost treatment had significantly greater microbial biomass than the one with inorganic fertilizers (Bhat et al., 1996).

Maintenance of soil fertility for sustainable agriculture needs agricultural methods and approaches that protect and enhance earthworm's activity. This review gathers some evidence about the fact that the input of vermicompost, instead of chemical fertilizers, promotes plant growth and boosts the yield with minimal disturbances in soil, being a viable and friendly agricultural practice that can be adopted for healthy and fertile soil.

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