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Vermicomposting of rice-straw and its effects on sorghum growth

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Abstract: Vermicomposting of rice-straw using three species of earthworms viz., *Perionyx excavatus* Perrier, *Octochaetona phillotti* (Michaelsen) and *Octonochaeta rosea* (Stephenson) was prepared. Plant nutrient contents of these vermicomposts and their effects on sorghum growth in relation to the effects of normal compost (without earthworms), that of chemical fertilizers (urea and single super-phosphate applied @ 40 kg ha^{-1}) and sole soil were investigated. Vermicompost produced by the three species of earthworms differed in their nutrient concentrations, but possessed higher concentration of total N and Ca than that of the normal compost. Vermicompost produced by *P. excavatus* possessed higher concentrations of total N, available P and K and Ca and Na than the compost produced by *O. rosea.* The growth of sorghum in the mixtures of 75% of vermicompost produced by *P. excavatus* and 25% soil was significantly higher than that of the plants grown in mixtures of vermicompost produced by *O. phillotti* and *O. rosea* and soil, normal compost, soil mixed with chemical fertilizers and sole soil.

Resumen: Se preparó vermicomposta de paja de arroz usando tres especies de lombrices de tierra, que son *Perionyx excavatus* Perrier, *Octochaetona phillotti* (Michaelsen) y *Octonochaeta rosea* (Stephenson). Se investigaron los contenidos de nutrientes vegetales de estas vermicompostas y sus efectos en el crecimiento del sorgo en comparación con los efectos de la composta normal (sin lombrices de tierra), de los fertilizantes químicos (urea y súper-fosfato simple aplicado en dosis de 40 kg ha^{-1}), y del suelo solo. La vermicomposta producida por las tres especies de lombrices de tierra difirió en sus concentraciones de nutrientes, pero tuvo concentraciones más altas de N total y Ca que la composta normal. La vermicomposta producida por *P. excavatus* tuvo concentraciones más altas de N total, P y K disponibles, y Ca y Na que la composta producida por *O. rosea.* El crecimiento del sorgo en las mezclas de 75% de vermicomposta producida por *P. excavatus* y 25% de suelo fue significativamente mayor que el de las plantas que crecieron en mezclas de vermicomposta producida por *O. phillotti* y *O. rosea* y suelo, composta normal, suelo mezclado con fertilizantes químicos y suelo solo.

Resumo: Usando três espécies de minhocas (*Perionyx excavatus* Perrier, *Octochaetona phillotii* (Michaelsen) e *Octonochaeta rosea* (Stephenson) foi preparada uma vermi-compostagem de palha de arroz. O teor em nutrientes destas vermi-compostagens e os seus efeitos no crescimento do sorgo em relação aos efeitos da compostagem normal (sem minhocas), ao da fertilização química (ureia e superfosfato simples aplicado na proporção de 40kg ha-1) e solo sem adições foi investigada. A vermicompostagem produzida com o recurso às três espécies de minhocas diferiram quanto à sua concentração de nutrientes, possuindo, no entanto, mais elevada concentração do N total e Ca do que o composto normal. A vermi-compostagem produzida pela *Perionyx excavatus* possuía uma concentração mais elevada de N total, P e K disponível, Ca e Na do que o composto produzido pela *Octonochaeta rosea*. O crescimento do sorgo cultivado com misturas de 75% de vermi-composto por *P. excavatus* e 25% de solo foi significativamente mais elevado do que aquele verificado com uma mistura de vermi-

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composto produzido por *O. phillotii* e *O. rosea* e solo, composto normal, solo misturado com fertilizantes químicos e só solo.

Key words: Chemical fertilizers, earthworm species, normal compost, rice-straw, sorghum, vermicompost.

Introduction

Rice – straw is the most important crop-residue in India with annual production reaching more than 105 mt (Gaur 1992), and it has a variety of uses such as bovine feed, thatch mulch and spent mushroom compost etc. and is finally dumped and composted. In States like Punjab, a huge quantity of rice-straw is burnt leading to loss of enormous amount of plant nutrients and causing air pollution. The usual composting of rice-straw occur in the compost pits of the farmers, where it is converted to a stable humus-like substance. Rice-straw can also be composted using earthworms, which may produce good quality compost. The use of earthworms in compost heaps, beds or boxes has fastened the process of breakdown of organic waste and its decomposition, i.e., composting (Edwards & Burrows 1989; Gaur & Sadasivam 1993). However, little information is available on the use of earthworms in composting of rice straw and plant-nutrient status of compost of rice-straw processed by earthworms in relation to the normal compost (without use of earthworms), and on the effects of these composts on plant growth (Harries *et al.* 1990). This paper presents an account of the plant nutrient contents of rice-straw compost produced by using species of earthworms and its effect on sorghum growth.

Materials and methods

Three species of earthworms, viz., *Perionyx excavatus* Perrier, *Octochaetona phillotti* (Michaelsen) and *Octonochaeta rosea* (Stephenson) were used for composting rice-straw during the present investigation carried out at the farmhouse of ICRISAT Asia Center. Individuals of *P. excavatus* were collected from a Vermicomposting unit, while those of *O. phillotti* and *O. rosea* were collected from the near by agricultural farm and the undisturbed natural re-vegetation area, respectively, inside the ICRISAT farm. They were maintained in rectangular plastic containers with the previously decomposed rice-straw for five days before using them in the present experiment.

Rice-straw was chopped to approximately 5 cm size and 60 to 70 kg of such chopped straw was moistened for a week by sprinkling water, and mixing frequently. Three replicates each with 5 kg of the moist straw were taken in separate rectangular plastic containers of size 35 x 45 x 20 cm. Twenty individuals of each species of earthworms were introduced in each replicate container. Simultaneously, rice-straw (5 kg) was composted normally without any earthworm in another set of three replicate containers. After about 75 days, the vermicomposts prepared with the earthworm species and the normal compost were collected in polyethene bags. These composted materials were air-dried, sieved and used for analysis of various chemical elements. The concentrations of available K, Ca, Mg and Na were estimated by the triacid digestion method (Jackson 1967) and atomic absorption spectrophotometer (Varian AA201). The total N and available P concentrations were analysed by a Technicon Auto Analyzer-II (Industrial Methods Nos. 218-72A and 114-7A, respectively). The organic carbon (OC) concentration was estimated by Walkely-Black procedure (Jackson 1967).

Pots of 23.5 cm height and 20.5 cm inner diameter each with 5 kg of mixture, sole agricultural field soil mixed with chemical fertilizers and soil and vermicompost and normal compost were used. Each of the vermicomposts with two different concentrations such as 75% and 25% mixed with 25% and 75% soil respectively, along with other treatments were used for growing sorghum plants in the glasshouse. The pot experiment with eleven treatments each with three replicates was set up with randomized block design and the details of the treatments are given as follows:

Treatment I – Soil with urea (N)+single superphoshate (P_2O_5) (@40 kg h^{-1}); Vermicompost (VC) produced by *P. excavatus*: Treatment II – 75% VC mixed with 25% soil; Treatment III – 25% VC mixed with 75% of Soil. VC produced by *O. rosea*: Treatment IV – 75% VC mixed with 25% Soil; Treatment V – 25% VC mixed with 75% Soil. VC produced by *O. phillotii*: Treatment VI – 75% VC mixed with 25% Soil; Treatment VII – 25% VC mixed with 75% Soil; Treatment VIII – Normal Compost (NC) – 75% NC mixed with 25% Soil; Treatment IX – 25% NC mixed with 75% Soil; VC produced by *P. excavatus*: Treatment X – VC top dressing (spread on the surface around the root); Soil alone: Treatment XI – Soil. Sorghum (*Sorghum bicolor* (L) seeds (variety CSH 19) were sown in the pots, which were watered regularly. Plant characteristics such as height (cm), shoot biomass (g), root length (cm), root biomass (g), number of leaves and leaf area (cm^{-1}) were measured and the data were analysed by two way ANOVA.

Results and discussion

The plant-nutrient status of vermicompost of rice-straw made with three species of earthworms presented in Table 1 showed that the rice-straw vermicompost processed by *P. excavatus* possessed higher amounts of total N, available P and K, Ca and Na compared to those of the rice-straw vermicompost composted by *O. phillotti* and *O. rosea* and the normal compost. However, the Mg content was higher in vermicompost processed by *O. rosea*. The quantities of total N and available P in vermicompost produced by *P. excavatus* were significantly higher than those of normal compost (ANOVA $P<0.01$). The concentrations of available P and K, Ca, Mg and Na were lower in vermicompost produced by *O. phillotti* and the total nitrogen and OC were lower in the normal compost. The vermicompost produced by *O. rosea* possessed higher amounts of all the nutrients except OC, than the vermicompost produced by *O. phillotti*.

Effects of the two concentrations of vermicompost produced by *P. excavatus, O. phillotti* and *O. rosea* on sorghum plant growth, in relation to that of sole soil, soil mixed with inorganic fertilizer and normal compost presented in Table 2 showed that the shoot and root biomass and their length, and the number of leaves, and leaf area were significantly higher in treatment II, i.e., mixture of 75% vermicompost of *P. excavatus* and 25% of soil than those of other treatments ($P<0.01$). These measurements were lower in treatment XI i.e., sole soil (Table 2). The plants grown in mixture of soil and higher concentrations (75%) of vermicompost produced by all the three species of earthworms showed greater growth patterns than those grown in mixtures of soil and lower concentrations (25%) of vermicompost ($P<0.01$) (Table 2). Plants grown in the treatment X, i.e. with vermicompost top-dressing showed increased growth compared to those of the sole soil (Table 2). However, these plants did not show any higher growth compared to those grown in treatments with mixture of 25% soil and 75% vermicompost produced by the three species of earthworms and even those of the plants grown in 75% soil and 25% of vermicompost produced by *P. excavatus*. It may indicate that the top-dressing may not be a suitable practice of application of vermicompost. Interestingly, the plants grown in the mixture of 75% vermicompost produced by *P. excavatus* and 25% soil showed higher growth compared to those of the plants grown in soil mixed with inorganic fertilizer ($P<0.01$) (Table 2). The plants grown in mixtures of soil and vermicompost produced by *O. rosea* showed higher growth except in shoot biomass, than plants grown

Table 1. Plant nutrient content of rice-straw composted using three species of earthworms in relation to that normal compost.

Nutrients	Normal Compost	Vermicompost		
		O.phillotti	*O. rosea*	*P. excavatus*
Organic C (%)	5.12	5.33	5.20	6.63
Total N (ppm)	2737	4152	4454	5513
Available P (ppm)	46.9	32.0	40.1	82.7
Available K (ppm)	1575	1285	1745	2480
Ca (ppm)	1786	1644	1859	1886
Mg (ppm)	516	490	614	574
Na (ppm)	425	329	459	549

Table 2. Effects of vermicompost on plant growth of Sorghum (*Sorghum bicolor* (L.)) grown in pot culture at ICRISAT (Patancheru, A.P.).

Treatments	Growth media	Plant height (cm)	Root length (cm)	No. of leaves (x)	Leaf area (cm^2)	Shoot biomass (g pot^{-1})	Root biomass (g pot^{-1})
I	Soil with N + P_2O_5	52.22	25.04	10.44	196.3	7.10	0.617
II	75% VCPe + 25% S	54.60	30.28	10.78	246.7	9.59	0.670
III	25% VCPe + 75% S	35.93	22.96	8.05	140.1	6.79	0.556
IV	75% VCOr + 25% S	48.86	27.08	9.41	188.1	4.54	0.600
V	25% VCOr + 75% S	30.97	18.24	8.39	126.1	2.93	0.533
VI	75% VCOp + 25% S	40.19	24.79	8.83	160.6	4.68	0.547
VII	25% VCOp + 75% S	30.01	16.54	7.50	103.5	2.94	0.466
VIII	75% NC + 25% S	28.42	15.66	7.06	51.5	2.79	0.466
IX	25% NC + 75% S	25.78	12.91	5.72	35.5	1.88	0.426
X	S with VCPeT	32.08	22.36	7.67	55.7	3.08	0.520
XI	Sole S	12.08	10.94	4.83	22.1	1.05	0.347

VC = Vermicompost; S = Soil; Pe = *P. excavatus*; Or = *O. rosea*; Op = *O. phillotti*; NC = Normal Compost (without earthworms); VCPeT = Vermicompost of *P. excavatus* top-dressing.

in the mixture of soil and vermicompost produced by *O. phillotti.*

There is good evidence that organic matter that pass through the gut of earthworm and deposited on or in the soil in the form of casts possessed higher amounts of plant-nutrients than that of the substrates or soil on which the earthworm feeds (Edwards & Burrows 1989; Reddy *et al.* 1997). Moreover, the nutrients are changed to assimilable forms in the gut, that are more rapidly taken up by the plants (Edwards & Lofty 1974; Lee 1985). The nutrient contents of casts and vermicompost vary greatly depending on the organic matter on which the earthworms feed. These excretory products also acquire the microbial metabolites while passing through the gut and the microbial metabolites act as plant growth promoting hormone-like substances (Tomati *et al.* 1995).

In the present study, elemental concentrations of the vermicompost produced by different species of earthworms differed and the elemental concentrations of vermicomposts particularly that of *P. excavatus* were significantly higher compared to those of normal compost ($P<0.01$). It indicated superiority of the vermicompost over the normal compost. The reduction in OC percentage of vermicompost produced by *O. rosea* was probably because of its deep-burrowing nature, and due to more efficient assimilation and utilization of organic matter in its gut. It has been reported that vermicompost possessed 1.60%, 2.20% and 0.67% (dry basis) of N, P_2O_5 and K_2O respectively (Misra & Hesse 1982). Cuban earthworm vermicompost contained 1.5 to 2.2% N, 1.8 to 2.2% P_2O_5, 1.0 to 1.5 K_2O, 10 to 11 C/N ratio, 3.5 to 4% humic acids and 65-70% organic matter (Rosset & Benjamin 1993). Harries *et al.* (1990) reported slightly higher N content in vermicompost (1.92%) than that of static pile compost (1.34%). They found that the nitrate (NO_3) concentrations of vermicompost were 4 to 10 times higher than that of static pile compost. However, P and K concentrations were higher in static pile compost. The relatively higher N content of vermicompost is of interest as it is an important growth-limiting nutrient.

There have been many reports that earthworms and their excreta increased the growth of different plants viz., clover, rye, spinach, peas, oat, barley and wheat in Europe (Edwards & Burrows 1989) and paddy (Reddy 1989) and sorghum (Reddy *et al.* 1994) in India. Vermicompost produced by *Eisenia foetida* and prepared from various decaying organic matter have been claimed to be useful as plant growth media for a wide range of plants (Edwards & Burrows 1989). They stated that the effects of vermicompost was not only better for seedling emergence but also for the growth of transplanted plants, and it is often better than the commercial plant-growth media.

In the present study, sorghum showed significantly higher growth in plant height, shoot biomass, root length, root biomass, leaf number and area in the mixtures of vermicompost and soil compared to the mixtures of normal compost and soil, and sole soil (ANOVA: $P<0.01$) (Table 2). The plants showed maximum growth in the aforementioned characteristics in the mixtures of 75% vermicompost produced by *P. excavatus* and 25% soil, which indicated its superiority over the vermicompost produced by other species of earthworms and even over the soil mixed with chemical fertilizer. The higher growth of various plant characteristics in vermicompost compared to other treatments was not only because of the presence of greater amounts most of the plant nutrients but also due to the presence of microbial metabolites, the plant-growth promoting hormone-like substances. The earthworm casts and vermicompost influenced the development of the plants and promoted stem elongation, root initiation and root biomass, which suggest the linkage between biological effects of vermicompost and microbial metabolites that influence the plant growth and development (Tomati *et al.* 1995). However, the quality of vermicompost and its effects on plant growth may depend on a variety of factors, which needs further investigations.

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