

EFFECT OF VERMICOMPOST APPLICATION ON THE SOIL PROPERTIES, NUTRIENT AVAILABILITY, UPTAKE AND YIELD OF RICE - A REVIEW

G. Sudhakar, A. Christopher Lourduraj, A. Rangasamy,
P. Subbian and A. Velayutham

Department of Agronomy,
Tamil Nadu Agricultural University, Coimbatore - 641 003, India

ABSTRACT

Earthworms can live in decaying organic wastes and can degrade it into fine particulate materials, which are rich in nutrients. Vermicomposting is the application of earthworm in producing vermifertilizer, which helps in the maintenance of better environment and results in sustainable agriculture. Earthworm make the soil porous and help in better aeration and water infiltration. Vermicompost can be prepared from different organic materials like sugarcane trash, coir pith, pressmud, weeds, cattle dung, bio digested slurry etc. Increased availability of nutrients in vermicompost compared to non-ingested soil resulted in significantly better growth and yield of rice has been reported by several workers.

The role of earthworm in the breakdown of organic debris on the soil surface and in the soil turnover process was first highlighted by Darwin (1881). Since then, it has taken almost a century to appreciate its important contribution in curbing organic pollution and providing topsoil in impoverished lands. Since 1978, there has been increasing interest in possible methods of processing organic wastes using earthworm to produce valuable soil additives. Earthworm is specialised to live in decaying organic wastes and can degrade it into fine particulate materials, which are rich in available nutrients with considerable potential as soil additives to revive the productivity status of soil. Earthworm can serve as nature's plowman and they form nature's gift to produce good humus by minimising the time of humification of organic materials. Vermicomposting is the application of earthworm in producing vermifertilizer, which helps in the maintenance of better environment and results in sustainable agriculture (Senapati, 1996). Earthworm can consume practically all kinds of organic wastes, consume two to five times its body weight and after using 5-10 per cent of the feed stock for its growth, excrete mucus coated undigested matter as

wormcasts. It is estimated that 1000 tonnes of moist organic matter can be converted by earthworms into 300 tonnes of compost (Gunathaliagaraj, 1994). In this review the available literature on the effect of vermicompost application on physical properties of soils, organic matter and nutrient availability, uptake of nutrients and crop growth and yield of rice crop are reviewed.

Effect of vermicompost on soil properties

Wormcasts are a resource that may be used in agriculture because of their effects on nutrient dynamic and the physical structure of soil may significantly enhance plant growth and conserve better soil status (Lee, 1985).

Soil physical properties: Earthworm casts are usually considered to be responsible for a good soil structure and improve soil physical properties i.e. infiltration, water retention and resistance to erosion (Rose and Wood, 1980). Lee (1985) reported that the hydraulic conductivity increased by 80% and water infiltration by six fold. Casenave and Valentin (1988) measured a five fold higher infiltration, if casts were present at the soil surface (10-15mm h⁻¹, than if they were absent (2mm h⁻¹).

Epigeic earthworms may deposit 20-

200 t dry soil ha⁻¹ surface casts year⁻¹ that contain a significant proportion of soil organic matter (Blanchart, 1990). Martin (1991) reported that earthworm casts had increased the proportion of macro-aggregates significantly from 25.4 to 31.2 per cent. Kale *et al.* (1992) found that the application of earthworm casts to fields can improve the physio-chemical and biological properties of the soil. The infiltration capacity is said to increase upto 130 mm hr⁻¹ against 10 mm hr⁻¹ of a conventional farm. This ensures ground water retention and prevents soil erosion. Apart from raising the water table, the earthworm act as bio-pump by transporting moisture from lower layers to upper ones (Bhawalkar, 1993). Lanchnicht *et al.* (1997) found increased macropore formation due to earthworm burrows, which could increase preferential flow pathways, and movement of N through the soil profile.

Effect of vermicompost on organic matter and nutrient availability

Effect on soil organic carbon content: Wormcasts ingested soil often have much higher content of soil organic carbon and nutrients than the surrounding soil (Lee, 1985). Mulongoy and Bedoret (1989) reported that organic carbon and total N contents were significantly higher in drilosphere than those of adjacent soil.

Casts deposited by earthworms may participate in the accumulation of organic matter through increased organic matter produced in the ecosystem and the protection of soil organic matter in structures of the drilosphere (Martin, 1991). The organic carbon content is increased by 4.1-21.0 per cent for burrow wall material and by 21.2-43.0 per cent for worm casts. The carbonate content from casts was reduced by more than 50 per cent (Zhang and Schrader, 1993). Kale (1994) reported that vermicastings replenished the organic matter content of the soils. The organic matter content in worm casts was about

four times more than in surface soil, with mean values of 48.2 and 11.9 g kg⁻¹ respectively (Khang *et al.*, 1994).

Available nitrogen: The enrichment of earthworm casts with available nutrients compared to the surroundings has been observed by Lee (1985). Earthworm reject significant amounts of nutrient in this casts. Nitrogen is mainly excreted as ammonium in the urine released by the worm, it is thus mixed with the soil and found in the casts (Laverack, 1963; Lee, 1985). Bouche and Ferries (1986) reported that ¹⁵N labelled nitrogen from earthworm was rapidly and almost entirely taken up by plants. The earthworm output comprises almost assimilable products of excretion such as ammonia and urea, which is rapidly mineralized. Thus it represents a potentially significant source of readily available nutrient for plant growth. Earthworm casts were micro site rich in available carbon and nitrogen (Sensson *et al.*, 1984). Earthworm contribution to the N turnover in cultivated soils ranged from 3 to 60 kg ha⁻¹ year⁻¹ (Crossley, 1988; Bostom, 1988). Increased availability of N in worm casts compared to non ingested soil has been reported by several workers (Tiwari *et al.*, 1989; Hullugalle and Ezumah, 1991).

Earthworm excretion of nitrogenous compound in urine and mucus may provide particularly labile N source for soil microbes. Earthworm urine contained primarily of ammonium and urea. Mucus composed of mucoprotein with low C:N ratio of 3.8 (Scheu, 1991). Lavelle and Martin (1992) inferred that mineralisation rates in the soil were increased by up to 10 per cent and this could lead to the release of significant amount of NH₄⁺-N. Blair *et al.* (1997) suggested possible mechanism whereby earthworm microbial interactions can increase soil N availability by reducing microbial immobilization and enhancing mineralisation. Bouche *et al.* (1997) found that

the worm activity can increase potential net N mineralisation rates and is to accelerate the transformation of N, after increasing availability. Increased nitrate levels were observed in the soil and dissolved organic nitrogen concentration in earthworm ingested plots (Subler *et al.*, 1997).

Available phosphorus: Worm casts ingested soils were rich in water soluble P (Gratt, 1970; Sharpley and Syers, 1976) and inorganic nitrogen (Watanabe, 1975) in comparison with non ingested soil material. The availability of P was enhanced in casts compared to non ingested soil (Sharpley and Syers 1978; Devleeschauwer and Lal, 1981; Tiwari *et al.*, 1989) due to increased solubility of P by high phosphatase activity (Syers and Springett, 1984).

Mansell *et al.* (1981) showed that incorporation of casts increased the short term availability of P derived from litter by a factor of approximately three. Mackay *et al.* (1982) have confirmed the effect of earthworm in increasing the availability of P. Basker *et al.* (1994) reported that the available P was higher compared to the surrounding soil due to soil ingestion by earthworm. Vasanthi and Kumaraswamy (1996) reported that the organic carbon content, available status of N, P, K, Ca, Mg and micro nutrients were higher in treatment that received vermicompost plus N, P and K than in the treatment with N, P and K alone.

Available potassium: The casts of earthworms contained two to three times more available K than surrounding soils. (Tiwari *et al.*, 1989; Becborodov and Khalbayeva, 1990; Hullegalle and Ezumah, 1991). Basker *et al.* (1993) reported that the availability of K was enhanced significantly following soil ingestion by earthworm and this must be due to the changes in the distribution of K between non exchangeable to exchangeable forms.

Earthworms can not increase the to-

tal amount of nutrient in the soil but can make them more available and they may increase the rate of nutrient cycling, there by increasing the quantity of nutrients available (Sharpley and Syers, 1997).

Effect of vermicompost on uptake of nutrients

Needham (1957) estimated that earthworm could process 50 per cent of the N input from plant residues accounting 38 per cent of the N uptake by plants. An important feature of vermicomposts during the processing at the various organic wastes by earthworms is that many of the nutrients that they contain are changed to forms that are more readily taken up by plants, such as nitrate or ammonium nitrogen, exchangeable phosphorus and soluble potassium, calcium and magnesium (Edwards, 1982). Jadhav *et al.* (1997) observed considerable increase in the uptake of major and secondary nutrients such as N, P, K, Ca, and Mg by rice under vermicompost treatment than FYM.

Nutrient composition of vermicompost

The quality of the vermicompost produced from organic wastes depends very much on the original material that was used, it cannot be expected that a product with excellent fertilizing qualities will be obtained from inferior quality raw material (Albanet *et al.*, 1988). Depending on the parent material, the casts can be very rich in available nutrients, allowing not only an immediate supply of plant nutrients, but also build up reserves for future crops. Casts have a superior bio active potential, containing plant growth hormones, enhanced levels of soil enzymes and high soil microbial populations (Tomati *et al.*, 1987). Buchanan *et al.* (1988) suggested that most of the vermicompost had higher values of available nutrients than the wastes from which they were formed. Earthworm casts typically have higher amount of total and available nitrogen, organic carbon, total and exchangeable calcium, mag-

nesium, potassium and available phosphorus compared to surface soils (Lavelle *et al.*, 1994).

The excreta or castings of earthworm was rich in the nutrients *viz.*, N, P, K, Ca and Mg (Gunathaliagaraj, 1994). Earthworm accelerated the mineralisation rate and converted the wastes in to casting with higher nutritional value and degree of humification (Albanel *et al.*, 1998). Apart from providing the more available nutrient to plants, plant growth regulators, which belonging to the auxin, gibberlin and cytokinin groups presented in the earthworm worked materials, are produced by wide range of soil micro-organisms, many of which live with in the casts (Tomati *et al.*, 1983). Earthworm casts had higher numbers of cellulolytic aerobes and hemicellulolytic, amyolytic, nitrifying and denitrifying bacteria than the soil in which they lived (Elliott *et al.*, 1990). Lee (1992) reported that microorganisms in the worm casts might fix atmospheric N in such quantities that are significant for the earthworm metabolism and as a source of nitrogen for plant growth. Hendriksen (1997) found that worm casts ingested with soil might create an even more favourable environment to plant growth because of the higher moisture content and availability of nutrient found in the fresh casts.

Effect of vermicompost on crop growth and yield of rice

Forgaste and Babb (1972) reported that the cast produced by worm feeding on organic substrate was an extremely homogeneous, fertile material suitable for plant growth. A study conducted by Kale and Bano (1986) in summer paddy (IR-20) found that the vegetative growth likes shoot weight, root weight, root and shoot length were influenced by the application of worm cast in better way than chemical fertilizer.

Reddy (1988) reported increased growth of rice after addition of cast material from earthworm. Kale *et al.* (1992) revealed that in lowland rice, applying vermicompost

improved uptake of nutrient, increased level of N, P and microbial load and higher level of symbiotic association resulted in increased effect on growth and yield. Ismail (1993) reported significantly higher yield of lady finger chillies, water melon and paddy by vermicompost application than FYM. Venkataratnam (1994) reported that organic vermicompost could help to produce additional yield of crops to an extent of 30 per cent than normal application of fertilizers. Application of vermicompost to crops had immediate benefits as the nutrient can be directly absorbed, when applied to direct sown rice, the seedlings turned dark green immediately after emergence (Gunathilagaraj, 1994). Angadi and Radder (1996) indicated that the use of vermicompost @ 2.5 t ha⁻¹ increased grain and straw yield of rice and could save 50 per cent of recommend N P K fertilizers in upland rice. Vasanthi and Kumaraswamy (1996) stated that the grain yield was significantly higher by the treatments that received vermicompost @ 5 t ha⁻¹ + N, P and K at recommended dose compared to the treatment received N, P and K fertilizer alone.

Integrated application of organic N through vermicompost, fertilizer N and bio-fertilizer enhanced the growth parameters, yield attributes and yield of rice (Jayabal and Kuppaswamy, 1996). Rani and Srivastava (1997) tested vermicompost for its ability to replace a proportion of the urea fertilizer. Supplying one third or one 1/4 of N as vermicompost increased plant height, grain yield and yield components of rice. Jadhav *et al.* (1997) stated that vermicompost was found to be a better source for increased plant growth, dry matter production and yield and indicated the possibility of substituting 50 kg N ha⁻¹ from the recommended dose of N than FYM which substituted 25 per cent N only. Nagarajan (1997) obtained higher net income by application of vermicompost in rice.

Edwards (1998) reported that

vermicomposts were an excellent source of nutrients to rice. Boral *et al.* (1997) revealed that vermicompost was superior to traditional method of using FYM. It reduced the application of inorganic fertilizer to a significant extent. Vermicompost was also effective in maintaining higher fertility status of the soil at residual stages which was considered to be beneficial for cultivation of succeeding crops.

Crop wastes and weeds as a source of vermicompost

Vermicomposting is a simple technology and could help to upgrade the value of the animal and crop wastes. Vermiculture technology was utilized to recycle sericulture farm waste into nutrient rich vermicompost. The vermicompost is rich in plant nutrients containing 1.875% N, 0.6% P₂O₅ and 1% K₂O besides various micronutrients like zinc, copper and iron (Das *et al.*, 1996). Various organic materials such as cattle dung, coir pith, brewery sludge, mango litter, vegetable wastes, horse dung, pongamia litter and pongamia blossoms were mixed in various ratio and combinations to obtain eight substrate for study of composting. The vermicompost obtained from these substrate were analysed for their nutrient value *viz.*, per cent carbon, nitrogen, phosphorus, potash, calcium, magnesium and sulphur. The N levels ranged from 1.4 to 2.17 per cent and carbon level from 23.6 - 30 per cent. The nitrogen and potassium levels in all the composts tested were significantly higher than those of FYM and cattle dung (Kubra Bano and Suseela Devi, 1996).

Ushakumari *et al.* (1996) found that vermicompost produced from banana wastes (leaves, pseudostem) and cattle manure in the ratio of 8:1 contained an average 1.5, 0.4 and 1.8 per cent N, P₂O₅ and K₂O, respectively. However, Prabha Kumari *et al.* (1996) reported

that when banana leaves mixed with cow dung in the ratio of 1:1 (on weight basis) was used as the feeding material for the worms, the C/N ratio and nutrient composition significantly differed during different periods of composting. Raut *et al.* (1996) used slaughterhouse waste, vegetable market waste, sericulture waste and sorghum stalk with soil in the ratio of 3:1 for vermicompost preparation. With the results, higher nutrient content and the survival of earthworm was noticed in slaughter house waste followed by vegetable market waste and least was recorded in FYM + soil (3:1) mixture.

Vasanthi and Kumaraswamy (1996) prepared vermicompost from different organic materials like sugarcane trash, ipomea, parthenium, *neem* leaves and banana peduncle to increase the yield of rice and the soil fertility status. Vermicomposts from the above substrate differed in nutrient content. Organic wastes such as coir pith, press mud, water hyacinth, weeds, cattle dung and bio digested slurry can be effectively used for the production of vermicompost. Regarding nutrient value of compost, vermicompost prepared by bio-digested slurry + weeds recorded higher N content followed by press mud + weeds. All the vermicompost contained appreciable quantity of micro nutrients (Jeyapaul and Kuppuswamy, 1997). Nagarajan (1997) used nitrogen rich green leaves (that are used for applying to wet land as green leaf manure) and vegetable wastes obtained from kitchen for vermicompost preparation and found that the casts were rich in available N, P, K content than the original content of waste material. The N content of the vermicompost material prepared from congress grass (*Parthenium hysterophorus*) and cotton stalks with cattle dung at various proportion was higher than the cattle dung (Ravankar *et al.*, 1997).

REFERENCES

- Albanel, E. *et al.* (1988). *Biol. Fertil. Soils*, 6: 266-269.
 Angadi, V.V. and Radder, G.D. (1996). In: Organic Farming and Sustainable Agriculture. National Seminar,

- G.B.P.U.A.T., Pantnagar. p. 34.
- Basker, A. *et al.* (1994). *Biol. Fertil. Soils*, **17**: 154-158.
- Basker, A. *et al.* (1993). *Soil Biol. Biochem.*, **25**(2): 1673-1677.
- Bechorodov, P. and Khalbayeva, A.V. (1990). In: Second Australian Conference on Grassland Invertebrate Ecology. Wellington, New Zealand.
- Bhawalkar, U.S. (1993). Turning Garbage into Gold. An Introduction to Vermiculture Biotechnology. Bhawalkar Earthworm Research Institute, Pune.
- Blair, J.M. *et al.* (1997). *Soil Biol. Biochem.*, **29**: 361-367.
- Blanchart, E. (1990). Ph.D Thesis, University of Rennes I, pp. 263.
- Bostom, (1988). *Pedobiologia*, **3**: 379-388.
- Bouche, M.B. *et al.* (1997). *Soil Biol. Biochem.*, **29**: 375-380.
- Bouche, M.B. and Ferries, J.R. (1986). In: Earthworms in Waste and Environmental Management. (Edwards, C.A. and Newhauser, E.F. eds.) SPB Academic Publishing, The Netherlands, 231-240.
- Boral, E. *et al.* (1997). *Soil Biol. Biochem.*, **29**: 431-439.
- Buchanan, M.A. *et al.* (1988). In: Earthworms in Waste and Environmental Management. (Edwards, C.A. and Neuhauser, E. eds.) SPB Academic Publishing, The Hague, the Netherlands. pp.241-249.
- Crossley, (1988). *Applied Ecol.*, **26**: 505-520.
- Darwin, C.R. (1881). The Formation of Vegetable Mould through the Action of Worms, with Observations on their Habits. John Murray, London. pp. 326.
- Das, P.K. *et al.* (1996). In: Organic Farming and Sustainable Agriculture. National Seminar, G.B.P.U.A.T., Pantnagar, p. 45.
- Devleeschauwer, P.R. and Lal, L.B. (1981). *Soil Biol. Biochem.*, **24**: 913-915.
- Edwards, C.A. (1982). Biology and Ecology of Earthworms. 3rd edn, Chapman and Hall, London, 426pp.
- Edwards, C.A. (1998). *Earthworm Ecol.* **5**: 372-373.
- Elliott, T.E. *et al.* (1990). *Geoderma*, **56**: 449-457.
- Forgaste, O.T. and Babb, M.R. (1972). *Dairy Sci.*, **55**: 870-872.
- Gratt, J.D. (1970). *Earthworm Ecol. Cult. Soils*, **10**: 107-123.
- Gunathilagaraj, K. (1994). *The Hindu*, 6.4.94.
- Hendriksen, (1997). *Biotech. Bioeng.*, **23**: 1812-1997.
- Hullugalle, N.R. and Ezumah, H.C. (1991). *Agric., Ecosystems and Environ.*, **35**: 55-63.
- Jadhav, A.D. (1997). *J. Maharashtra agric. Univ.*, **22**: 249-250.
- Jayabal, A. and Kuppaswamy, G. (1997). In: Food Security in Harmony with Nature. 3rd IFOAM-ASIA Scientific Conference and General Assembly p. 61.
- Kale, R.D. and Bano, K. (1986). In: Proc. Nat. Semi. on Organic waste Utilization. pp: 151-160.
- Kale, R.D. (1994). *The Hindu*, dt.9th Feb.
- Kale, R.D. *et al.* (1992). *Soil Biol. Biochem.*, **24**: 1317-1320.
- Khang, B.T. *et al.* (1994). *Soil Fert. Soils*, **18**: 193-199.
- Kubra Bano and Suseela Devi, L. (1996). In: Organic Farming and Sustainable Agriculture. National Seminar: G.B.P.U.A.T, Partnagar. p: 37.
- Lachnicht, S.L. *et al.* (1997). *Soil Biol. Biochem.*, **29**: 493-498.
- Lavelle, P. and A. Martin. (1992). *Soil Biol. Biochem.*, **24**: 1491-1498.
- Lavelle, P. *et al.* (1994). In: The Biological Management of Tropical Soil Fertility. TSBF/Wiley-Sayce. pp.137-169.
- Laverack, C.H. (1963). In: Taxonomy and Geography (Nichols, D. ed.), pp.3-5, Syst. Assoc. Pub., London.
- Lee, K.E. (1985). Earthworms, their Ecology and Relationships with Land Use. Academic Press, Sydney, pp. 411.
- Lee, K.E. (1992). *Soil Biol. Biochem.*, **24**: 1765-1771.
- Mackay, P. *et al.* (1982). *Pedobiologia*, **18**: 153-157.
- Mansel, G. *et al.* (1981). *Applied Soil Ecology*, **3**: 263-274.
- Martin, A. (1991). *Biol. Fertil. Soils*, **11**: 234-238.
- Mulongoy, K. and Bedoret, A. (1989). *Soil Biol. BioChem.*, **23**: 609-617.
- Nagarajan, S. (1997). *Kisan World*, **24**(8): 49-50.
- Needham, A.E. (1957). *J. Exp. Biol.*, **34**: 425-445.
- Prabha Kumari, P. *et al.* (1996). In: Organic Farming and Sustainable Agriculture. National Seminar, G.B.P.U.A.T., Pantnagar p.35-36.
- Rani, R. and Srivastava, O.P. (1997). *Int. Rice Res. Notes*. **22**(3):30-31.
- Raut, R.S. *et al.* (1996). In: Organic Farming and Sustainable Agriculture. National Seminar, G.B.P.U.A.T., Partnagar. p: 35.
- Ravankar, H.N. *et al.* (1997). Food Security in Harmony with Nature. 3rd IFOAM-ASIA Scientific Conference and General Assembly: p. 57.

- Reddy, T.Y. (1988). Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Scheu, S. (1991). *Biol. Fert. Soils*, **12**: 217-220.
- Senapati, B.K. (1996). In: Proceedings and Recommendations. National Workshop on Organic Farming for Sustainable Agriculture: 187-189.
- Sharpley, A.N. and Syers, J.K. (1976). *Soil Biol. Biochem.*, **8**: 341-346.
- Sharpley, A.N. and Syers, J.K. (1978). *Soil Biol. Biochem.*, **4**: 1629-1633.
- Sharpley, A.N. and Syers, J.K. (1997). *Biol. Agric. Hort.*, **10**: 47-52.
- Subler, S. *et al.* (1997). *Soil Biol. Biochem.*, **29**: 413-421.
- Subler, A.V. *et al.* (1997). *Soil Sci. Soc. Am. J.*, **52**: 764-769.
- Ismail, S.A. (1993). Composting through earthworms. In: Monograph series on the engineering of photosynthetic systems. Shri. AMM. Murugappa Chettiar Research Centre Taramani. Madras.
- Syers, J.K. and Springett, J.A. (1984). *Pl. Soil*, **76**: 93-104.
- Tiwari, K.N. *et al.* (1989). *Fert. News*, **25**(3): 3-20.
- Tomati, U. *et al.* (1987). In: On Earthworms. Mucchi Editore, Modena, Italy, pp.423-435.
- Tomati, U. *et al.* (1983). *Agrochimica Acta*, **27**: 244-251.
- Vasanthi, D. and Kumaraswamy, K. (1996). Organic Farming and Sustainable Agriculture. National Seminar. G.B.P.U.A.T., Pantnagar. p:40.
- Venkataratnam, L. (1994). Food Security in Harmony with Nature. 3rd IFOAM-ASIA Scientific Conference and General Assembly: p. 59.
- Watanabe, R.A.S. (1975). Proc. of the New Zealand Grassland Association, **13**: 108-175.
- Zhang, H. and Schrader, S. (1993). *Biol. Fert. Soils*, **15**: 229-235.