Biocompost and Pill-Millipedes

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Soil Biodiversity

Soil is an important media and supports abundant organisms to carry out several essential ecosystem services. Diverse community of soil organisms perform key ecosystem services like decomposition of organic matter, sequestration of carbon, biological nitrogen fixation, nutrient cycles, detoxification of recalcitrant compounds, pest control and improvement of soil structure favourable for the growth of plants. Decreased diversity of organisms in soil owing to anthropogenic interference and improper management of agricultural lands or forests hampers the ecological functions leading to deterioration of soil structure as well as its functions. It is important to maintain high level of soil biodiversity for sustainable productivity in agriculture as well as forestry. A scientific effort called Global Soil Initiative by the European Commission has brought out an important document Global Soil Biodiversity Atlas to understand the soil biodiversity and its relevance in human existence (https://www.globalsoil biodiversity.org/atlas-introduction)

Organic Matter

The remains of biodegradable organic matter on the soil surface are called litter, which constitute leaves, inflorescence, buds, bracts, flowers, fruits, bark, twigs, branch, wood, roots, insect scales, whole dead insects, dead parts of other animals and so on. Forests produce such organic wastes and those debris accumulate on the floor continuously, which supports diverse saprophagous microbial as well as animal population. Agricultural residues as lignocellulosic organic matter (straw, seed coat, fruit wastes, roots and others) are generated in huge quantities. In spite of abundant renewable lignocellulosic wastes produced globally, only about 4-13% are appropriately utilized (or renewed) for productivity.

Organic matter decomposition initiates at the stage of senescence of plant parts, which will continue after deposition on the soil. The process of decomposition governed by physical and chemical changes in organic matter leads to mineralization called humus formation. Humus is a transformed pool of organic matter without recognizable plant or animal parts. Transformation of organic matter into humus follows a cascade of physical and chemical reactions geared up by soil organisms. Substantial information is available on the primary and secondary produces in different ecosystems. However, productivity, food webs and pattern of energy flow in the decomposer food chain is scanty although it the primary phase of energy transfer to the higher tropic levels.

There are several concrete options to utilize the lignocellulosic organic matter such as production of food (mushrooms), energy (methane and ethanol) and vermicompost (using earthworms). The last option is to allow the lignocellulosic organic matter to decompose on its own to narrow down its C/N ratio (Carbon/Nitrogen ratio), thus useful for application in agricultural production. Production of *in situ* or *ex situ* compost and vermicompost are the alternatives to provide desired nutrients to the plants. Selection of organic matter, processing, production, harvest and amendments are different steps of compost production. Besides, instead of mere application of composts into soil, it is possible to amend with plant growth promoting rhizobia (PGPR) (which fixes atmospheric nitrogen) and fungi involve in absorption of desired nutrients from the soil (arbuscular- and ecto-mycorrhizal fungi convert rock phosphate into easily absorbable orthophosphate). The main product of organic matter decomposition is humus, which is necessary to support the plant growth as well as to maintain the diversity of soil organisms. One of the most important qualities of humus is its narrow C/N ratio (~20:1). If the ratio is high (rice straw, 80:1), locked up nitrogen and phosphorus will not be available to plants immediately. That means, the nitrogen and phosphorus (not unlimited in soil) present in the humus is immediately available to the plants.

Soil Organic Carbon

According to the Indian Council of Agricultural Research (ICAR), currently our agriculture is suffering severely owing to decreased levels of soil organic carbon (SOC). The average SOC stock of Indian soils has decreased to 0.3-0.4%, which is 4-5 times below the desired level (1-1.5%). The reasons for such a drastic decrease of SOC is due to over exploitation, mining, indiscriminate use of agricultural chemicals (pesticides and fertilizers), soil erosion, unsatisfactory crop management and increased temperature. The only option to uplift the SOC to the desired level is to amend as much organic matter as possible to the soil (as mulch, green manure, organic matter and compost). Such amendments support the diversity of soil organisms to perform normal functions to retain the carbon stock in the soil on long-term basis. Burning lignocellulosic wastes has become an easy task to condense and eliminate the huge organic matter. It is scientifically not tenable due to pollution and severe loss of several useful components necessary to increase the soil carbon stock. Approaches of encouraging the activity of saprophagous fauna (e.g. earthworms and millipedes), solely dependent on the organic matter in the soil will help increasing the SOC stock.

Soil Macrofauna

Soil macrofauna (measuring more than 2 mm) is one of the major segments of soil biodiversity. Among them earthworms, millipedes, beetles, ants, termites, woodlice, insect larvae and snails perform vital role in organic matter processing and decomposition to maintain diverse microfauna as well as microbes. Such functions of macrofauna leads to addition of sufficient organic matter into soil leading to enhance biogeochemical cycling of nutrients, infiltration of rainwater, retention of moisture and reduction of rate of soil erosion. Millipedes (class, Diplopoda) are the major macrofauna responsible for mechanical fragmentation of organic matter leading to accumulation of fecal

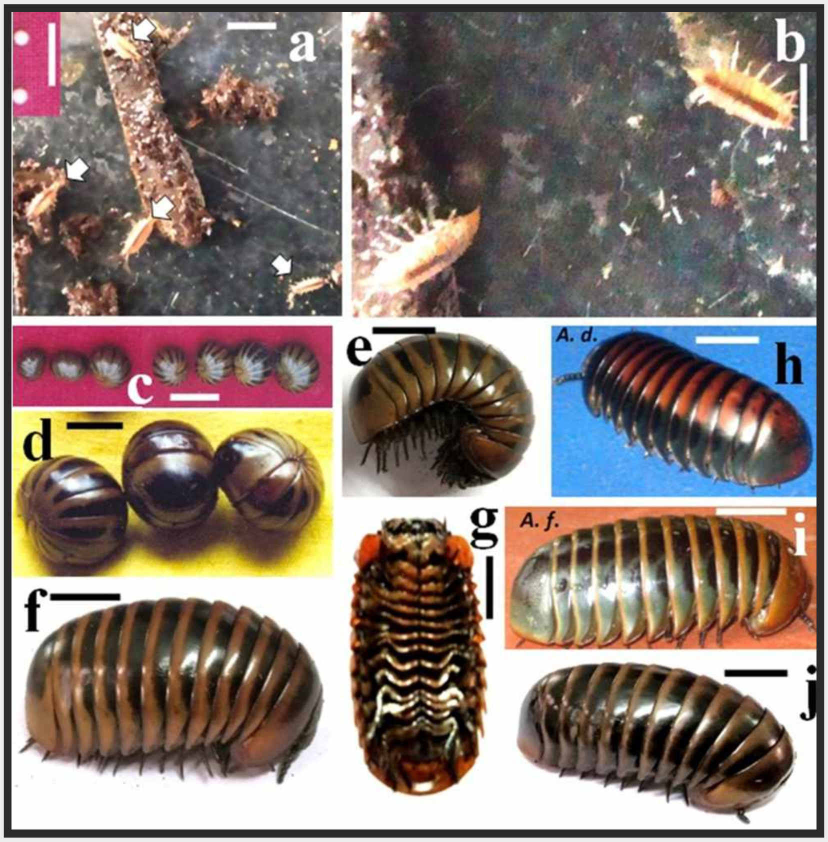

Fig. 1. Eggs (inset) (a), juveniles (arrows) (a, b), growth stages (c), conglobated (d), partially opened (e), moving (f) and ventral view (g) of *Arthrosphaera magna* common in Sampaje and coastal regions of Karnataka; *A. disticta* (h) common in Shimoga region; *A. fumosa* (i) common in Madikeri region and *A. carinata* occur along with *A. magna* in coastal region (Adyanadka and Manila) (j) (Scale bar, 1 cm).

pellets with rich proportion of bacteria and fungi in soil (Hopkin and Read, 1992). Giant pill-millipedes (order, Sphaerotheriida; genus, *Arthrosphaera*) roll-up into a marble or up to a baseball size as a protective measure against the predators (Wesener et al., 2010). According to Dangerfield and Telford (1991), pill-millipedes have lifespan up to 11 years. They are endemic to tropical regions and currently distributed in Southern India, Sri Lanka, Madagascar and parts of Southeast Asia. Up to 40 species of *Arthrosphaera* distributed in Southern India (Attems, 1936).

Pill-millipedes in the Western Ghats

Western Ghats is the hub of pill-millipedes and over 25 years of observations in the forests and plantations of Karnataka revealed occurrence up to 25 morphospecies (Ambarish and Sridhar, 2013). They are common in the southwest monsoon and post-monsoon seasons in the reserve forests, wildlife sanctuaries, agroforests and mixed plantations (e.g. *Acacia*, *Areca* and coffee). Surprisingly, they are also inhabitants of forests, scrub jungles and plantations of the west coast of Karnataka and Kerala (Adyanadka, Anekal, Manjanady, Manila, Mulleria and Uppala). These pill-millipedes prefer organically managed forests and plantations rather than locations where agrochemicals are added. Pill-millipedes are sensitive to a slight change in the edaphic factors (such as soil temperature, soil texture and litter thickness). Thus, they serve as authentic bioindicators of soil health and soil fertility. Occurrence of pill-millipedes in the forests and organically managed plantations of the Western Ghats and west coast will be a boon to exploit them in the management of the lignocellulosic wastes.

Biocompost by Pill-Millipedes

Pill-millipedes serve as suitable candidates for production of compost as they feed organic matter voraciously and produce fecal pellets in huge quantities. In many organically managed plantations, activity of pill-millipedes is common in the tree basins with large quantity of fecal pellets. Pill-millipedes could be reared in the laboratory with least efforts. *Arthrosphaera magna* lay eggs in the basins of coconut or *Areca* basins and rear the young ones (Fig. 1a-c). They roll (conglobate) in to sphere or marble by enclosing ventral parts to avoid disturbance or to evade predators (Fig. 1d). Availability of suitable substrate on its surroundings provides signal to open up (Fig. e) and proceed towards its food for foraging (Fig. 1f). Pill-millipedes possess strong mandibles, a pair of sensitive antennae, 13 segments (tergites) with laterally concave overlapping thoracic shields (first shield collum bulldoze the soil) and strong legs facilitate to mix the soil as well as drive its body into the deeper zones (Fig. 1g). Besides *A. magna* (common in Sampaje and coastal region of Karnataka), other common pill-millipedes are *A. disticta* (in the forests of Shimoga region) (Fig. 1h) and *A. fumosa* (in the forests of Madikeri region) (Fig. 1i). Another pill-millipede which is associated with *A. magna* in the coastal plantations of Karnataka is *A. carinata* (Fig. 1j). The most preferred organic matter for *A. magna* is coconut or *Areca* leaflets (Fig. 2a) and it is a commonly seen to form considerable quantities of fecal pellets in the basins (Fig. 2b).

First and foremost aspect of organic matter processing is breakdown of organic matter into small particles that could be achieved by the saprophagous fauna. They increase the surface area of the organic matter, which facilitates colonization of microbes for further degradation. The compost produced using pill-millipedes had 5-fold increase in the quantity of particles having size less than 5 mm (Ashwini and Sridhar, 2006). Such breakdown of organic matter will be an indication of efficient compost production by pill-millipedes. Decreased particle size of the organic matter results in increased surface area, reduced bulk density, increased water holding capacity and increased air space between the particles. Several observations and experiments have been carried out to follow the distribution of pill-millipedes and their activity in the forests, mixed plantations and laboratories (Ashwini and Sridhar, 2006; Ambarish and Sridhar, 2013). Pill-millipedes prefer the mixed leaf litter diet than single litter diet leading to increase the contents of nitrogen and phosphorus, while decrease the phenolic contents and C/N ratio in fecal pellets (Ashwini and Sridhar, 2006; Kadamannaya and Sridhar, 2009). Amendment of pill-millipede compost to grow cowpea and finger millet resulted in high biomass of root and shoot with high root nodulation in cowpea (Ambarish and Sridhar, 2013).

Management

Up to 75% of pill-millipede population could be maintained on the mixed leaf litter diet throughout the year with proper monitoring of temperature and moisture. Compared to *ex situ* production of vermicompost using earthworms, production pill-millipede compost is not complicated due to high rate of bioconversion, handling organic matter (no need to shred the organic matter), transfer of individuals and separation of fecal pellets will be easier than the earthworms. Urban organic wastes like leaf litter and grass shreds are ideal biocomposting material by the pill-millipedes (Sridhar and Ambarish, 2013). A model bin has been proposed to produce millipede compost (Fig. 1c). It has provision to add leaf litter + pill-millipedes, sprinkle water, monitor temperature and collect fecal pellets below the mesh located at the middle region of the chamber.

Owing to soil pollution and alarming rate of deforestation, recognition of soil fauna like pill-millipedes and its utilization and compost production is most important step towards ecofriendly management of agriculture as well as biodegradable wastes. Such ecofriently activities have been initiated recently in the campus of

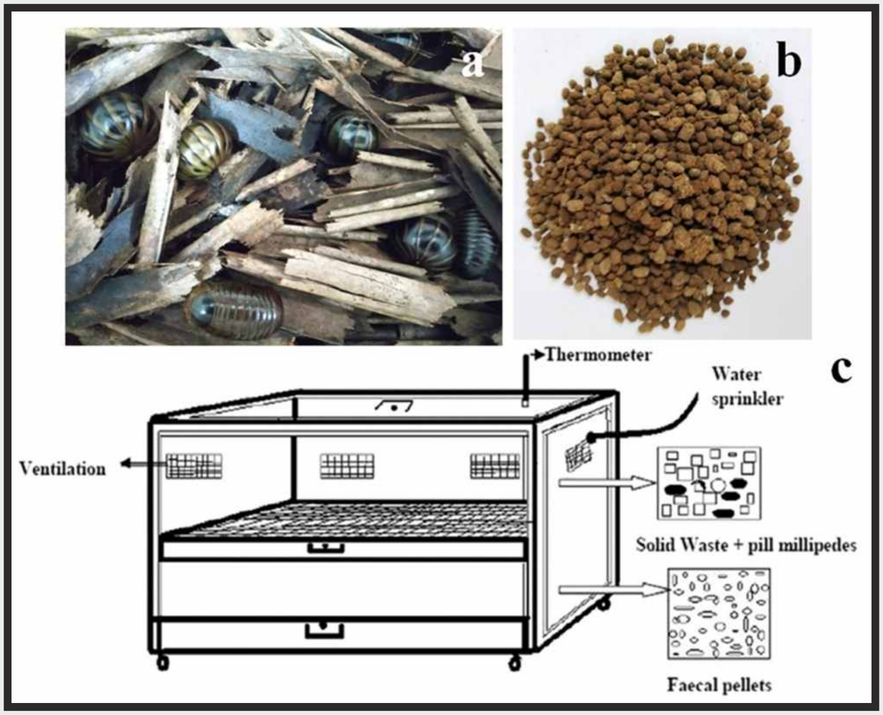

Fig. 2. *Arthrosphaera magna* foraging on coconut leaflet shreds (a) and its semi-dried fecal pellets (b); model bin could be used in compost production (source: *Current Science*, *104*, 1545, 2013).

Yenepoya (Deemed to be University) to produce and utilize pill-millipede compost using suitable organic wastes (leaf litter and grass shreds) produced in the campus area.

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