intensity facilitating species identification (Figure 1 *b*). It is evident from the present study that the segregation of *Rauvolfia* seeds through storage protein profiling by SDS–PAGE is reliable and reasonable.

1. Ladizinsky, G. and Hymowitz, T., *Theor. Appl. Genet.*, 1979, **54**, 145–151.
2. Pallares, L., Ferrari, L. and Ritta, M., *Seed Sci. Technol.*, 2000, **28**, 769–777.
3. Ghafoor, A., Ahmad, Z., Qureshi, A. S. and Bashir, M., *Euphytica*, 2002, **123**, 367–378.
4. Agarwal, P. K., Singh, D. and Dadlani, M., *Seed Sci. Technol.*, 1988, **16**, 563–569.
5. Lowry, O. H., Rosebrough, N. J., Farr, A. L. and Randall, R. J., *J. Biol. Chem.*, 1951, **193**, 265–275.
6. Davis, B. J., *Annu. N.Y. Acad. Sci.*, 1964, **121**, 404–427.
7. Laemmli, U. K., *Nature*, 1970, **227**, 680–685.
8. Koranyi, P., *Seed Sci. Technol.*, 1989, **17**, 153–159.
9. Hames, B. D., *Gel Electrophoresis of Proteins – A Practical Approach*, Oxford University Press, 1998, pp. 1–352.
10. Cherry, J. P., Katterman, F. R. H. and Endrizzi, J. E., *Theor. Appl. Genet.*, 1970, **42**, 218–226.
11. Johnson, B. L., *Am. J. Bot.*, 1972, **59**, 952–960.

ACKNOWLEDGEMENT. We thank the Director, JNTBGRI, Thiruvananthapuram for providing the necessary facilities.

Received 24 October 2011; revised accepted 1 June 2012

C. ANILKUMAR*
CHRIS IPE
S. BINDU
C. R. CHITRA
P. J. MATHEW
P. N. KRISHNAN

Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Palode, Thiruvananthapuram 695 562, India
**For correspondence.*
e-mail: tsbpalode@gmail.com

Evaluation of millicompost versus vermicompost

Increase in the human population, indiscriminate growth of cities, industrialization and agricultural practices have led to an increased accumulation of waste materials[1]. As nature is unable to degrade the huge quantity of wastes in a short period of time, these materials can act as a secondary host of diseases and pests[2]. All these problems forced us to revive the old traditional techniques of compost production and organic farming, which are nature's ways for the renewal of life. This results in loss of potentially valuable materials that can be processed as fertilizer, fuel and fodder. The biological treatment of these wastes appears to be most cost-effective and carries a less negative environmental impact[3].

To restore soil health, the practice of organic farming and encouraging the activities of soil invertebrates in agriculture is an essential step. The principal economic values of soil macroinvertebrates include soil turn-over, incorporation of organic matter into the mineral horizons, improvement of soil aeration by creating cavities, conversion of organic nitrogen and phosphorus into plant-assimilable forms, stimulation of soil respiratory enzymes, dispersion of microbial propagules and preservation of soil structure through humification. Biocomposting is an environmentally sound technology (EST) according to the criteria defined by the United Nations Environmental Programme (UNEP). Composting improves soil structure, texture and aeration and increases the water-holding capacity of the soil. The organic matter in the compost provides food for microorganisms, which keep the soil in a healthy, balanced condition; nitrogen, potassium and phosphorus will be produced naturally[4].

Earthworms are major component of the soil system and represent a key component in nutrient cycling of soils. The role of earthworms in organic matter decomposition, nutrient recycling of soil structure and plant productivity has been studied in detail[5]. The microorganism present in the gut of earthworm helps in degradation of organic materials[6]. Hence, the use of earthworms for waste conditioning is widely practiced all over the world for vermicomposting technology[7]. Vermicomposting is an eco-friendly technique involving no pollution and hence is the most suitable method for solid waste disposal when compared to conventional methods like land-filling, incineration, biogas production, etc.

Similarly, millipedes are known to be macrodetrivores terrestrial arthropods feeding on decaying vegetables matter and mineral soil and are represented by more than 80,000 species. They are essentially soil-dwelling and in some ecosystems, they are more important than worms as agents of soil and nutrient turnover. Although millipedes are often called 'thousand leggers', they actually have far fewer legs, and each body segment has two pairs of short legs. Millipedes do not bite or pose any danger to humans. Martens *et al.*[8] reported that earthworms and millipedes are important members of the detritus food web in the agricultural ecosystem and both use manure as the food source. Microorganism plays a crucial role in the digestion of millipedes by breaking down the cellulose into simple sugar. Further, it is reported that the degradation of organic matter and recycling of detritus energy are favoured by the gut microbes of millipedes[9]. Like earthworms, millipedes improve the soil structure and enrich the soil with nutrients. Even though millipedes are the major saprophagous fauna, so far no sufficient information is available on using millipedes for compost production. Hence, the present study is made to explore the efficiency of millipedes in converting the organic waste into useful fertilizers and comparing them with earthworms.

The raw materials for the present study, flowers of the discarded garlands, were collected from the historic Meenakshi Sundareswarar Temple in Madurai city. The predominant flower wastes of the garland include: *Jasminum sambac* (jasmine), *Calendula officinalis* (marigold), *Gomphrena globosa* (Globe Amaranth or Bachelor Button), *Celosia spicata* (cockscomb) and petals of *Nelumbo nucifera* (lotus). They were shredded into small pieces and dried for a week. The flower waste was mixed with equal amount of fresh cow dung in plastic troughs separately and allowed for predigestion by sprinkling water. After 30 days, the predigested substrates were subjected to vermicomposting and millicomposting. The adult millipede, *Arthrosphaera magna* was collected from the reserve forest of Alagarmalai Hills and earthworm (*Eisenia fetida*) was collected from the SACS vermiery, near Chatrapatty, Madurai District, Tamil Nadu. They were acclimatized to the laboratory conditions for one month before the start of the experiment.

E. fetida, popularly known as red wriggler, red worm, tiger worm, etc., is perhaps the most widely used earthworm for vermicomposting (Figure 1 *a*). Mature individuals can attain the body weight up to 1.5 g. Each mature worm on an average produces one cocoon every third day and from each cocoon (on hatching within 23 days) 1–3 individuals emerge. *A. magna* belongs to the class Diplopoda, order Sphaerotheriida and family Sphaerotheriidae (Figure 1 *b*). Adults have exactly 12 segments and each segment has two pairs of legs. The head of the adult is yellow-brown or olive-brown or olive green; the second segment (collum) and other segments are dark brown with a black band bordered with light yellow colour, forming a narrow stripe. The average weight of the millipede is 10.5 g.

Three kilograms of the moist predigested material (of flower wastes) was

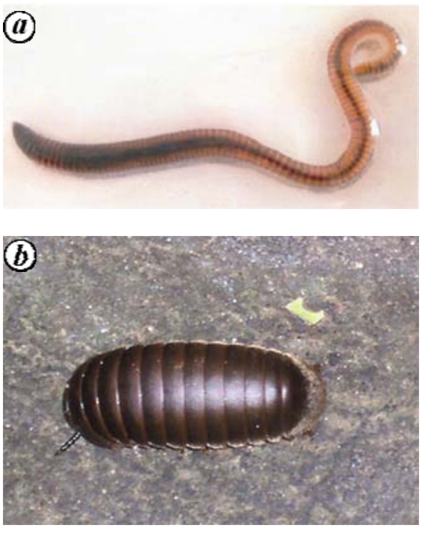

Figure 1. ***a***, Earthworm, *Eisenia fetida* and ***b***, Millipede, *Arthrosphaera magna*.

taken in separate six rectangular culture troughs of equal size (47 × 32 × 16 cm). Among these, six, two were without the composting organism and were labelled as 'conventional compost' or control. Fifty individuals of millipede species, *A. magna* were introduced separately in two troughs and labelled as 'millicompost' and 50 individuals of *E. fetida* were introduced in the remaining two troughs and labelled as 'vermicompost'. Water was sprinkled at regular intervals in all the troughs to maintain moisture content of 65–75% at a temperature of 25°C. The troughs were covered with wet muslin cloth to prevent the invasion of foreign materials and the escape of millipedes and earthworms. The biocomposting process was extended for 60 days. Spraying of water was stopped two days before the harvest. Before introducing the millipedes into the troughs, i.e. at the first day and after day 30 and day 60, samples of compost, vermicompost and millicompost were collected for analysis of physico-chemical characters.

The pH of the sample was measured by using a pH Meter (Systronics; Model 335). Electrical conductivity (EC) was determined with the help of an electrical conductivity meter (Elico; Model CM 180). To quantify the soil organic carbon, Walkley and Black's rapid titration methods was followed[10]. Total nitrogen was determined using micro-Kjeldhal method[11]. Phosphorus was estimated by Vogel method[12]. Available potassium and calcium were detected using the Flame photometer (Elico; Model CL 378). To assess the efficiency of different composts on plant growth, a pot experiment was conducted. Seeds of chilli plant, *Capsicum annuum*, were purchased from Agriculture College and Research Institute, Madurai. They were surface-sterilized with 0.1% mercuric chloride and then sown in three earthenware pots separately (9 cm dia) and filled with 60-day-old conventional compost, vermicompost and millicompost derived from flower waste. For each compost, three replicates were maintained. After 45 days, growth parameters, viz. height of the plant, number and area of the leaves, number and weight of the fruits and chlorophyll content of the leaves were determined.

At the end of 30 and 60 day period, significant difference was found in all biochemical components of millicompost compared to vermicompost and conventional compost (Table 1). Higher nitrogen content was observed in millicompost (0.96%) than vermicompost (0.92%) and conventional compost (0.89%). Similarly, higher phosphorus content was found in millicompost (0.85%) compared to vermicompost (0.76%) and conventional compost (0.61%). The potassium content was maximum in millicompost (0.73%). Similarly, very high amount of calcium (2.78%) was noticed in millicompost followed by vermicompost (2.46%) and conventional compost (1.45%). There was remarkable decrease in the carbon content in millicompost (21.24%) after day 60. It was 23.28% and 26.32% in the vermicompost and control respectively (Table 1). The C/N ratio was maximum (36.46) in conventional compost at the first day and found to decrease in compost processed by millipede (22.35) when compared to compost prepared by earthworms (25.30). The EC value increased from 1.46 mS/cm (0 day) to 2.65 mS/cm and 2.17 mS/cm in millicompost and vermicompost respectively. At the end of day 60, the pH was found to decrease. It was 8.2, 6.8 and 6.6 in conventional compost, vermicompost and millicompost respectively.

Data related to the effect of different composts processed by *A. magna* and *E. fetida* on the growth parameters of *C. annuum* are presented in Table 2 and Figure 2. The results revealed that the plant grown on flower wastes processed by *A. magna* attained maximum height (37.1 cm) compared to vermicompost (32.8 cm) and compost (26.6 cm). Similarly, other parameters, including number of leaves (58.6/plant) and area of leaves (4.26 sq. cm), number (11/plant) and weight (3.12 g) of the fruits and total chlorophyll content (2.55 mg/g fresh wt) were greater in millicompost. Though the plants grown on residues of vermicompost processed by *E. fetida* showed lesser height (32.8 cm), number (42.0/plant) and area (3.58 sq. cm) of leaves, number (8.0/plant) and weight (2.23 g) of fruits and chlorophyll content (2.70 mg/g fresh wt) were found to be higher when compared to the plants grown on the conventional compost.

The soil macrofauna is known to play a significant role in the disintegration and decomposition of organic material added to the soil[13]. Vermicomposting is a simple biotechnological process of composting, in which certain species of earthworm are used to enhance the

Table 1. Physico-chemical characteristics of the study samples

Parameters	First day	Day 30			Day 60		
		Cc	Vc	Mc	Cc	Vc	Mc
pH	8.2 ± 0.65	7.4 ± 0.51	6.3 ± 0.50	6.5 ± 0.58	7.1 ± 0.63	6.8 ± 0.47	6.6 ± 0.59
EC (mS/cm)	1.46 ± 0.11	1.68 ± 0.15	2.08 ± 0.16	2.13 ± 0.14	1.73 ± 0.13	2.17 ± 0.15	2.65 ± 0.21
N (%)	0.81 ± 0.06	0.84 ± 0.07	0.88 ± 0.06	0.91 ± 0.07	0.89 ± 0.07	0.92 ± 0.07	0.96 ± 0.07
P (%)	0.52 ± 0.03	0.58 ± 0.04	0.70 ± 0.05	0.74 ± 0.05	0.61 ± 0.04	0.76 ± 0.06	0.85 ± 0.06
K (%)	0.54 ± 0.04	0.57 ± 0.05	0.63 ± 0.05	0.68 ± 0.05	0.60 ± 0.04	0.65 ± 0.05	0.73 ± 0.05
C (%)	29.46 ± 2.6	28.71 ± 2.5	25.64 ± 2.3	22.16 ± 1.9	26.32 ± 2.3	23.28 ± 2.0	21.24 ± 1.9
Ca (%)	1.24 ± 0.09	1.33 ± 0.10	1.68 ± 0.13	2.09 ± 0.14	1.45 ± 0.11	2.46 ± 0.19	2.78 ± 0.26
C/N ratio	36.46 ± 3.2	34.17 ± 3.1	29.13 ± 2.6	24.35 ± 1.9	29.57 ± 2.3	25.30 ± 2.2	22.35 ± 2.0

Cc, Conventional compost; Vc, Vermicompost; Mc, Millicompost; EC, Electrical conductivity.

Table 2. Effect of flower waste residues composted with earthworm and millipede on the growth parameters of *Capsicum annuum* at 45 days after sowing. Each value represents mean and standard deviation

Parameters	Compost	Vermicompost	Millicompost
Height of plant (cm)	26.6 ± 2.12	32.8 ± 2.95	37.1 ± 2.96
Number of leaves	39.3 ± 3.53	42.0 ± 3.36	58.6 ± 5.27
Leaf area (sq. cm)	3.08 ± 0.24	3.58 ± 0.28	4.26 ± 0.38
Fruit number	4.94 ± 0.39	7.5 ± 0.60	10.6 ± 0.95
Fruit weight (g)	1.22 ± 0.10	2.23 ± 0.17	3.12 ± 0.26
Chlorophyll (mg/g fr. wt)	1.79 ± 0.14	2.07 ± 0.16	2.55 ± 0.22

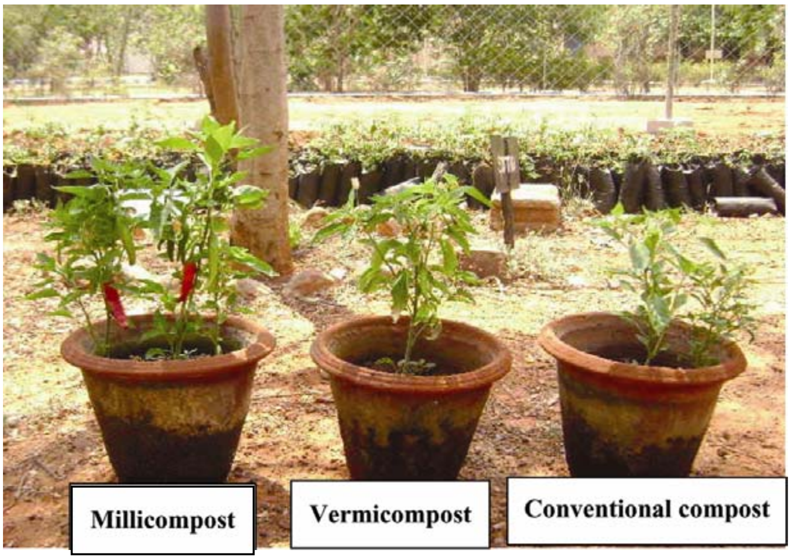

Figure 2. Effect of flower waste processed by *A. magna* and *E. fetida* on *Capsicum annuum*.

process of waste conversion and produce a better end-product. Millicompost is the process in which millipedes are employed for composting vegetable and plant waste[14]. Earthworms consume various organic waste and reduce the volume by 40–60%. Each earthworm weighs about 1.0–1.5 g, eats waste equivalent to its body weight and produces cast about 50% of the waste it consumes in a day, but mature millipedes eat organic waste about five times their weight[15]. Similar figures have been found for other temperate millipede species[16]. Dangerfield[17] reported that the millipede feeding activities may have considerable effect on the regulation of the decomposition process and may be beneficial to crop production by retarding nutrient release by locking up nutrients in persistent faecal material. Diplopods are herbivorous and detritivorous; they feed mainly on decomposing vegetation but some species eat decaying animal tissues such as the Lysiopetalids that inhabit rocks[18]. In some tropical regions, these millipedes are more important than earthworms in soil recycling[19]. Our results indicate that nitrogen, phosphorus, potassium and calcium were higher in millicompost than vermicompost. Hence, the following factors have been found to be different in millipede faeces versus the original litter[20]: (i) more available carbohydrates and amino acids; (ii) higher nitrogen levels; (iii) more moisture due to compaction of the pellets or otherwise; (iv) a pH of 6.5 and (v) the change in physical structure of the pellet compared to the parent litter. With the decomposition of litter, holocellulose is degraded to soluble carbohydrates used by organisms soon after production, as seen by the high respiration quotient in the faeces during the first weeks[21]. This increase in carbon utilization has been confirmed by other studies as well[22]. The processing of litter by millipedes decreases the carbon–nitrogen ratio in the faecal pellets. This is mostly caused by the increase in nitrogen compounds with relatively little change taking place in the amount of carbon compounds. Increase in nitrogen has been found by many researchers[23,24]. Moreover, Webb[25] observed an increased level of nitrogen fixation through the production of NH_3 in the pellets. The presence of millipedes positively changes the concentration of many nutrients like phosphorus, calcium and magnesium[24,26]. The rise in pH and the availability of ammonia make millipedes faeces offering a pleasant environment to microflora and other organisms[23,27]. The increased level of nitrogen in the millicompost may be due to the excretory products of the millipedes and by the microorganisms in the millipede faeces[9]. High degree of decomposition and mineralization increases the high nitrogen content of the soil in significant quantities and also act as a vital source of nitrogen for plant growth[28]. Higher concentration of elements was found in compost derived from millipedes than that from earthworm. However, the concentration of nitrogen and phosphorus increased due to digestion and faecal pellet formation in pill millipede *A. magna*. Maraun and Scheu[29] reported that the concentration of nitrogen and phosphorus was found to be increased by the activity of *Glomeris marginata*. Nicholson *et al*.[21] observed that ash and phosphorus were high in faecal pellets of millipedes. Similarly, McBrayer[30] reported that the faecal pellets of millipedes also increased the pH, moisture and bacterial count, and decreased fungal count and carbon compared to undigested leaf litter. The narrow C/N ratio in treated samples indicates the enhancement of respiration, influenced by the activities of *A. magna* as reported by Aswini and Sridhar[31].

Millipedes can disrupt the movement of nitrogen from litter to mycorrhizae through their feeding, which increases the mobilization of nitrogen in the substrate[32]. Consumption of millipede faeces by other organisms may also be required in some cases. Earthworm communities deprived of the presence of millipede; and millipede faeces lost 37% of their initial weight[33]. The present study indicates that among the composting species chosen for the present study, millipede, *A. magna* is highly efficient in composting the waste into useful organic manure than earthworm, *E. fetida*. Physico-chemical characters were significantly higher in millicompost when compared to vermicompost. Ashwini and Sridhar[34] reported increase in the concentration of N, P, K, Ca and Mg in compost produced with the help of millipede and earthworm. Prabhas *et al*.[35] showed that millicompost is superior and has a positive effect on plant growth over vermicompost and ordinary compost.

1. Munnoli, P. M., *Dynamic Soil Dynamic Plant*, 2010, pp. 1–21.
2. Kale, R. D. and Krishnamoorthy, R. V., *Pedobiologia*, 1982, **23**, 419–425.
3. Suthar, S., *Int. J. Plant. Prot*., 2009, **3**, 1035–1043.
4. Appelhop, M., University of Marine Co-operative Extension, Bulletins, 2003, p. 1143.
5. Lavelle, L. G., In Proceedings of the Seminar on Resources of Soil Fauna in Egypt and Africa (eds Gabbour, S. I. and Davis, R. C.), Cairo, 1988, pp. 16–17.
6. Edwards, C. A. and Bholen, P. J., In *Biology and Ecology of Earthworms*, Chapman Hall, London, 1996, 3rd edn, pp. 35–55.
7. Senapathi, P. K., In Proceeding and Recommendations: National Workshop on Organic Farming for Sustainable Agriculture, 1996, pp. 187–189.
8. Martens, M. M., Alphei, J., Schaefer, M. and Scheu, S., *Isot. Environ. Health Stud*., 2002, **37**, 43–51.
9. Alagesan, P., Ashok Kumar, B., Muthukrishanan, J. and Gunasekaran, P., *Indian J. Microbiol*., 2003, **43**, 111–113.
10. Jackson, M. L., In *Soil Chemical Analysis*, Prentice Hall of India Pvt Ltd, New Delhi, 1973.
11. Umbreit, W. W., Burris, R. H. and Stauffer, J. F., In *Manometric and Biochemical Techniques*, Burges Publ. Co, Minnesota, USA, 1972, 5th edn, p. 259.
12. Vogel, A. I., In *A Textbook of Quantitative Inorganic Analysis including Elementary Instrumental Analysis*, The English Language Book Society and Longman, 1963, III edn, pp. 115–125.
13. Neuhauser, E. F. and Hertenstein, R., *Pedobiologia*, 1978, **18**, 99–109.
14. Karthigeyan, M., M Phil dissertation, Madurai Kamaraj University, Madurai, 2004.
15. Blower, J. G., *Symp. Zool. Soc. London*, 1974, **32**, 527–551.
16. Hopkin, H. P. and Read, H. J., *The Biology of Millipedes*, Oxford Press, Oxford, 1992, pp. 95–115.
17. Dangerfield, J. M., *Pedobiologia*, 1990, **34**, 141–150.
18. Ruppert, E. E., Fox, R. S. and Barnes, R. D., *Zoologia dos invertebrados: Uma abordagem functional-evolutiva*. Sao Paulo, *Editora Roca*, 2005, 7th edn, pp. 56–78.
19. Costaneto, M., *Acta Boil. Colom*., 2007, **12**, 123–134.
20. Lodha, B. C., In *Biology of Plant Litter Decomposition* (eds Dickinson, C. H. and Pagh, J. F.), Academic Press, New York, 1974, vol. 1, pp. 213–241.
21. Nicholson, P. B., Bocock, K. L. and Heal, O. W., *J. Ecol*., 1996, **54**, 755–766.
22. Rawlins, A., Bull, I. D. and Ineson, P., *Soil Biol. Biochem*., 2006, **38**, 1063–1076.
23. Carcamo, H. A., Prescott, C. E., Chanaway, C. P. and Abe, T. A., *Can. J. For. Res*., 2001, **31**, 1195–1204.
24. Smit, A. and Van Aarde, R. J., *Funct. Ecol*., 2001, **15**, 51–59.
25. Webb, D. P., In *The Role of Arthropods in Forest Ecosystem* (ed. Mattson, W. J.), Springer-Verlag, USA, 1977, pp. 57–69.
26. Kaneko, N., *Ecol. Res*., 1999, **14**, 271–279.
27. Ghilarov, M. S., On the interrelations between soil dwelling invertebrates and soil microorganisms. In *Soil Organisms* (eds Doeksen, J. and Vander der Drift), Oosterbeek Publishers, The Netherlands, 1963, pp. 181–186.
28. Hair, T. K., Thankamani, R. V. and Sushama, P. K., *Agrobios*, 2004, **3**, 18–20.
29. Maraun, M. and Scheu, S., *Oecologia*, 1996, **107**, 131–140.
30. McBrayer, J. F., *Pedobiologia*, 1973, **13**, 90–98.
31. Aswini, K. M. and Sridhar, K. R., *Curr. Sci*., 2002, **82**, 20–22.
32. Anderson, J. M., Leonard, M. A. and Ineson, P., *Soil Biol. Biochem*., 1985, **17**, 735–737.
33. Bonkowski, M. S., Scheu, S. and Schaefer, M., *Appl. Soil Ecol*., 1998, **9**, 161–166.
34. Ashwini, K. M. and Sridhar, K. R., *Curr. Sci*., 2006, **90**, 954–959.
35. Prabhas, C. T., Apurva, P. and Shailendra, K. S., *Adv. Appl. Sci. Res*., 2011, **2**, 94–98.

ACKNOWLEDGEMENTS. We thank the University Grants Commission, New Delhi for providing grants in the form of a major research project, which also included project fellowship to the first author.

Received 14 December 2011; revised accepted 15 May 2012

B. RAMANATHAN
P. ALAGESAN*

Post Graduate and Research,
Department of Zoology,
Yadava College,
Madurai 625 014, India
**For correspondence.*
e-mail: maniragavi@rediffmail.com