hardly any scope of expansion because of pressure on agricultural land for food and cash crops. (6) The solution, therefore, lies in maximizing forage production in space and time, identifying new forage resources, increasing forage production within the existing farming systems, utilizing marginal and sub-marginal dry lands and problem soils for developing feed and fodder resources. (7) The monsoonal grasslands of India are also impoverished, overgrazed and infested with bushes. (8) *Phalaris* is a noxious weed in the wheat fields of India as chicory is in legume crop fields, and both should be kept out of our prime irrigated cropping systems.

In the Indian context, fodder chicory cultivation is not feasible to be taken up under the farming systems, as it continues to be an obnoxious weed. However, it is recommended for introduction and cultivation in national parks, sanctuaries, etc. where along with grasses, it may constitute a nutritive fodder for wild animals and forage for the declining population of insect pollinators.

1. Shukla, G. P. and Patil, B. D., *Forage Res.*, 1985, **11**, 1–19.
2. Punjab Singh, Report, Indian Grassland and Fodder Research Institute, Jhansi, 1988.
3. Chatterjee, B. N. and Das, P. K., *Forage Crop Production: Principles and Practices*, Oxford & IBH, New Delhi, 1989, pp. 288–299.
4. Sarveshwara Rao, D., Sonika, Meenakshi Singhal and Priya Kansal. *Indian J. Plant Genet. Resour.*, 2001, **14**, 224–226.
5. Sarveshwara Rao, D., Sonika and Prem Prakash. In *Advances in Legume Research in India* (eds Rao, R. R. and Choudhary, L. B.), Bishan Singh Mahendra Pal Singh, Dehra Dun, 2002, pp. 401–409.
6. Yogeshwar Singh, In Proceedings of the International Conference on Apiculture in Tropical Climates, Division of Entomology, IARI, New Delhi, 29 February–4 March 1980, p. 6.
7. Anon., *The Wealth of India (Raw Materials)*, CSIR, New Delhi, 1988, vol. 2, pp. 75–100.
8. Li, G. and Kemp, P. D., *Adv. Agron.*, 2005, **88**, 187–222.
9. Swaminathan, M. S., Ministry of Agriculture, Government of India, 2004–06.

ACKNOWLEDGEMENTS. I am grateful to Prof. P. S. Satsangi Sahab, Chairman, Academic Advisory Committee, DEI, for inspiration and Prof. V. G. Das, Director, DEI for encouragement. I thank to Soami Pyari and Subhash Chandra Biyan for help.

Received 6 July 2007; revised accepted 23 October 2008

D. SARVESHWARA RAO

Farming Systems Research Unit,
Botany Department,
Dayalbagh Educational Institute (Deemed University),
Agra 282 005, India
e-mail: dsrao_fsr@yahoo.co.in

Soil aggregation by vermicompost of press mud

Investigations were made to recycle agro-industrial wastes for the production of vermicompost using earthworm, *Eudrilus eugeniae* and bacterial inoculum (with viable count 168×10^9/g/ml) at laboratory scale. The vermicompost obtained was studied in a petri plate system for aggregation of soil. One gram of vermicompost derived from press mud using *E. eugenae* and bacterial inoculum was found to retain 74.10% on 90 µm sieve, indicating that 20 g of 90 µm soil is bound by the vermicompost. This property of vermicompost appears to have potential use for soil erosion-control measures, acting as a micro dam which holds water.

Soil aggregation plays an important role in the soil–air ecosystem and provides the bases for the life-supporting system of micro flora and fauna. (The weathering cycle of formation of soils and rocks gives rise to solid rock formation and vice versa, i.e. soil formation due to physical agencies like wind, air, water, climatic changes, etc.) The soil formed has to be maintained on a long-term basis and this is the role of microbes to hold together the soil solids. The present-day barren and waste lands need to be looked upon by researchers as a challenge to recover the lost flora and fauna by reducing soil erosion. Therefore, an experiment on vermicompost is presented specially with reference to soil aggregation property, which brings a correlation between vermicompost soil and the microorganisms.

The vermicompost of press mud (1 g) using *E. eugenae* and bacterial inoculum with viable count 168×10^9/g/ml was used in the experiment.

One gram of this vermicompost was placed in a petri dish. Using a sterilized, straight wire, the vermicompost was spread all around aseptically as shown in Figure 1 *a*. Next 20 g of industry soil passed through 90 µ sieve was spread above the vermicompost as shown in Figure 1 *b*. The plates were observed at every 2 h interval. The plates shown in Figure 1 *a* and *b* taken after 10 h are shown in vertical and inverted positions.

Sieve analysis was carried out according to the standard procedure[1] using IS sieves. Figure 1 *c* and Figure 2 show the cohesive nature of forces brought about by inoculating 1 g of vermicompost by virtue of their positions, whereas Figure 1 *a* and *b* show stable casts and soil poured on the casts. The soil was firmly held in a vertical position; and an inverted position indicates that microbes present in the vermicompost and their water-holding capacity are responsible for the formation of stable aggregation. The formation of aggregation of soil also reduces soil erosion in the field. The water-holding capacity which was above 100%, an important property of vermicompost due to its amorphous nature, can be utilized during drought conditions as mini reservoirs or micro dam. This will allow maintaining the health of the soil for longer periods. Microbes in 1 g of vermicompost with cfu 100×10^9/ml/g can hold 20 g of soil in position. Water from the vermicompost is released when dry conditions prevail in the environment. The microbes identified as sporulating bacilli can survive in adverse conditions. When the moisture levels in the soil are regained during the rainy season, microbes

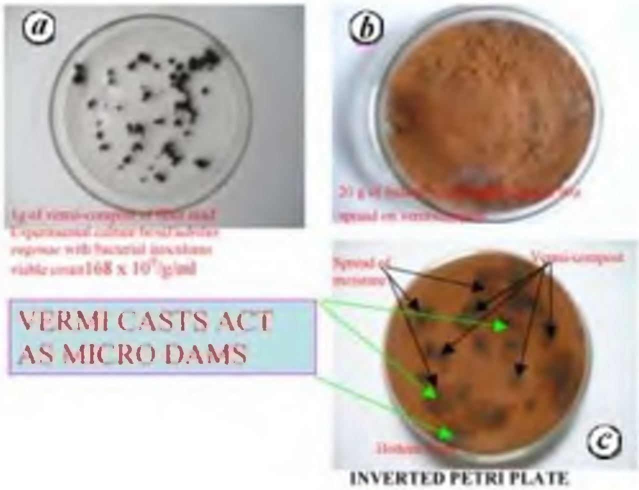

Figure 1. Vermicompost as micro dams.

Figure 2. Soil held vertical and inverted in position in petri plates.

Figure 3. Pie diagram of sieve analysis.

Table 1. Results of sieve analysis carried out after 30 days

Particle size (µ)	Weight retained (g)	% retained	Cumulative % retained	Cumulative % finer (N)
90	0	0.00	0.00	100
90	14.82	74.10	74.10	25.9

become active and continue their metabolic activities.

This experiment also demonstrates the tensile strength added to the soil by vermicompost, which was held freely when the petri plate was inverted. The tensile strength derived could be from the polysaccharides content of the microorganisms.

As the soil used in the experiment was passed through 90 µ that is the best possible small fractions available with respect to surface area in the laboratory is also one of the factors for the microorganisms to act upon to bring the desired changes in soil aggregation. The results of the sieve analysis presented in Table 1 and Figure 3 show the diagrammatic presentation of aggregation of soil, which was found to be retained on 90 µm sieve. Bhandari *et al.*[2] reported that earthworms formed water-stable aggregates, which reduced the soil erosion.

It has been reported that *Pheritima elongata*, when used with potato peel waste in open vermi beds, leads to aggregation of soil[3]. Similar aggregation property of vermicomposts was reported by several workers[4–7].

Aggregation of the soil becomes an important factor as far as the percolation of water and water-holding capacity of soil are concerned. The vermi-cast is rich in micro and macronutrients. Therefore, aggregation of the soil with vermi-cast also leads to storage of nutrients. The nutrients are released to the plants as and when required.

A more realistic answer to soil aggregation can be given by the theory of soil structure genesis. One of the answers could be that soil colloids, clay particles, organic and inorganic compounds have high electro-kinetic potential and repel each other in colloidal suspensions, but flocculate when the potential is lowered significantly. Stable aggregation formation, however, requires cementation or binding together of primary and flocculated particles, so that they are held firmly and do not dispense in water[8,9].

1. Punmia, B. C., *Soil Mechanics and Foundation Engineering*, Standard Book House, New Delhi, 2001, pp. 1–121.
2. Bhandari, G. S., Randhwa, M. S. and Naskina, M. S., *Curr. Sci.*, 1967, **36**, 519–520.
3. Munnoli, P. M., Arora, J. K. and Sharma, S. K., In *Waste Resource Recycling in the*

Developing World (eds Jana, B. B. *et al.*), 2000, pp. 203–208.
4. Kale, R. D. and Krishnamoorthy, R. V., In *Progress in Soil Biology and Ecology in India* (ed. Veeresh, G. K.), UAS Tech. Series, 1981, vol. 37, pp. 64–68.
5. Bhawalkar, V. and Bhawalkar, U., *Vermiculture Biotechnology*, BERI, Pune, 1992, pp. 1–60.
6. Singh, N. B. and Arora, J., Thesis on development of process package for organic solid waste management through vermiculture biotechnology, in organic waste generating industries in Punjab, T.I.E.T. Patiala, Punjab (deemed University), 1997, pp. 91–93.
7. Munnoli, P. M., Arora, J. K. and Sharma, S. K., *J. Ind. Pollut. Control*, 2002, **18**, 87–92.
8. Ghildyal, B. P. and Gupta, R. P., Report, ICAR, New Delhi, 2002, pp. 1–55.
9. Edwards, A. P. and Bremner, J. M., *J. Soil Sci.*, 1967, **18**, 45–64.

ACKNOWLEDGEMENTS. We thank Prof. Sunila Mavinkurve for her support and encouragement. The funding received from CAPART is thankfully acknowledged.

Received 14 December 2007; revised accepted 23 October 2008

P. M. MUNNOLI[1,*]
SAROJ BHOSLE[2]

[1]*Agnel Polytechnic, Verna, Goa 403 722, India*
[2]*Microbiology Department, Goa University, Goa 403 206, India*
**For correspondence.*
e-mail: prakashsunanda@rediffmail.com

Hunting of Indian giant squirrel (*Ratufa indica*) by the lion-tailed macaque (*Macaca silenus*) in the Western Ghats, India

In most primate species, with the exception of Colobinae and Indriidae, faunal prey constitutes a significant portion of the diet[1]. The prey mainly includes arthropods and small vertebrates. The type of prey species varies with the body size of the primate species, with small-bodied primates such as prosimians feeding mainly on insects. The relatively large-bodied primates included small vertebrates such as lizards, birds, small mammals, etc. in their diet[2–4]. Occurrence of larger vertebrate prey such as hare, fawn of antelopes and other species of monkeys has been reported in the diet of large-bodied primates such as chimpanzees and baboons[5,6]. Consumption of large vertebrate prey has also been reported in capuchins[7]. Hunting, in terms of pursuit, capture and consumption of large vertebrate prey, has been well documented in chimpanzees[6,8,9], baboons[5,10] and capuchins[7]. Most macaques have an omnivorous diet with varying proportions of fruits, leaves, flowers, arthropods and, to some extent, small vertebrates[3,11–13]. The lion-tailed macaque (*Macaca silenus*) is an endangered species endemic to the evergreen forests of the Western Ghats, India. Its diet mainly consists of fruits, arthropods, flowers and other minor items such as moss, mushroom and grass[14,15]. The Indian giant squirrel is a large, diurnal, arboreal squirrel. It is widely distributed in peninsular India and occurs in the Western Ghats, Eastern Ghats and Central India[16]. The squirrel inhabits mainly moist deciduous, riverine and evergreen forests. Average body weight of an adult squirrel[17] is about 2 kg with a body length of 35–41 cm and tail length of about 60 cm. Here we report an incident of predation on a sub-adult Indian giant squirrel (*Ratufa indica*) by an adult, male, lion-tailed macaque.

This incident took place during our study on resource partitioning among sympatric, diurnal, arboreal mammals in the evergreen forests of the Indira Gandhi Wildlife Sanctuary, Tamil Nadu, India. The study site, Pachchapalmalai Shola (10°24′35.38″N and 77°0′31.34″E), is an evergreen forest fragment with an area of about 3.5 km^2. The diurnal, arboreal mammalian community at the study site consisted of two groups of lion-tailed macaques, ten groups of Nilgiri langur (*Semnopithecus johnii*), two visiting groups of bonnet macaque and several individuals of the Indian giant squirrel[18]. Two individuals of the Indian giant squirrel were chosen for the study and observations were made using *ad libitum* and scan sampling[19].

The following observations were made by one of the authors (H.S.S.). On 29 April 2001, at 9:20 am a few individuals from the study group of lion-tailed macaques were foraging for insects in the canopy. A sub-adult Indian giant squirrel, which was resting on a branch, jumped down to the ground and started to scurry. An adult male of the lion-tailed macaque group quickly descended to the ground and chased the squirrel for a distance of about 30 m. He hit the squirrel on its head with one swipe, pinned it to the ground and carried it off to a tree by holding it by the scruff of its neck. It was still alive when the monkey started to bite its head. In a few seconds, the squirrel was dead. The monkey ripped-off the skin on its head and started to eat the flesh around the neck. None of the other group members showed any interest, except a sub-adult male who came to the tree in which the adult male was present and sat in proximity. When the adult male finally dropped the carcass, the sub-adult male quickly descended to the branch from which the carcass hung and grabbed it. Not much was left of the squirrel, except a few parts of the viscera, half-eaten limbs and tail.

Faunal prey is an important component in the diet of the lion-tailed macaque. Although feeding on vertebrates is not frequent, there have been sporadic reports of lion-tailed macaques foraging on frogs, lizards, bats, small birds, three-striped squirrels, nestlings of the Indian giant squirrel and the large, brown, flying squirrel[11,13,20]. There is also one report of an unsuccessful attack on a mouse-deer fawn by the lion-tailed macaque[13], though it is not clear whether it was an attempt to predate upon the deer. While feeding on arthropods and smaller prey is common among most age-sex classes in the lion-tailed macaque, foraging on larger prey is mainly reported among the adult males[13]. All of the previous incidents suggest that the prey was detected at a close range and captured. This tactic of capturing of prey – scavenge hunting – requires least specialized predatory skills and energy and is characteristic of