On Earthworms. A. M. Bonvicini Pagliai & P. Omodeo (eds.). Selected Symposia and Monographs U.Z.I., 2, Mucchi, Modena, 1987, pp. 519-531

MARCEL B. BOUCHÉ

Emergence and Development of vermiculture and vermicomposting: from a hobby to an industry, from marketing to a biotechnology, from irrational to credible practices

ABSTRACT

Since the first vermiculture heaps owing the fish baits selling, numerous events have occured about the use of epigeous earthworms. The diverging uses and the variety of people and economics dealing with vermicomposting and vermiculture lead to a great diversity of practices and skills. After a short history about the transformation of such practices, the author tries to describe the stage of the art and the related engineering.

Key words: Vermiculture.

1. Introduction

The breeding of earthworms on organic matter is gradually becoming one of the promising biotechnologies. Nothing is certain yet, because the future is not written in the present, and even less in the past, but this activity evolves in such a rapid and diversified manner, that concrete applications, lastingly profitable and socially useful, should not result from it.Today this technology is undergoing very rapid innovations and it also opens unexpected and very promising applications, and yet it remains marked by the past has created the actual situation: a constructive past, but also one tainted by shadows.

The earthworms, constituting the first animal mass of the emerging temperate environments, tropical and equatorial, *should have*, from this point of view, beneficied of basic and fundamental studies proportional with their importance. Unfortunately, the means that have been dedicated to these obscure, disgusting, invisible and nevertheless omnipresent animals amount probably to somewhere between one thousandth and the ten-thousandth part of the means spent for micro-organisms and for vegetables (20 times more important).

It is necessary to be conscious of the state of the art of the advancement of knowledge to be able to work efficiently for the development of this young biotechnology. On the other hand, because of the dispersal of means, the diver-

sity of local conditions, and the multitude of applications it is difficult to understand the present state of affairs in this field.

As a contribution however, I shall try to trace the evolution of vermitechnology and if possible put into order this fluid sphere. Each historical phase appears as a new awareness of a possibility – not always honest – for lucrative if not efficient activities. I shall thus make an effort to present our technology through its historic-technical context (and scientific... but there one has to be very modest!).

2. Emergence of vermiculture: Bait for fishing

Populations in the collecting-hunting stage of evolution directly consumed earthworms gleaned here and there, as testified by the various peoples that all over the world are at present at this socio-economical stage, and indeed eat the earthworms gathered during their wanderings. In order to establish the first indirect rational use of earthworms perhaps one should go back to the first man who fashioned a fishhook. For a long time, the search for bait was the individual task of each angler, but our social evolution has led to the restriction of authorized fishing periods (not always when earthworms are easy to collect), it also led to considering this activity as a relaxation without lucrative aims, and lastly to separate man from nature so far that, the collecting of baits becoming difficult, even dissuasive, commercial trading in bait has been developed.

It is not surprising that in the USA where the proportion of rural men was already very low during the first half of the 20th century, the commerce of earthworm baits was established very early. In addition, it seems that in general on the new continent these animals are far less abundant because of paleogeographic causes of marginal implantation of Lumbricidae – initially without «anecics» (Bouché, 1984); an urban society, a poor earthworm fauna, the development of hobbies favour in the US the boom of a commerce which became evident through advertisements in newspapers from the 30s: vermiculture is born.

This vermiculture derives directly from exploitation of dungheaps dear to anglers. The only notable difference is that the vermiculturist organizes his work, takes care of his dungheap in order to obtain under optimal conditions a maximum of commerciable baits. This economical practice is and will remain a lucrative practice, it is however limited to a restricted and seasonal outlet.

3. The bluff: the «soil-ution»

In 1949, the book by T. J. Barrett appeared which marked a turning point

in vermiculture: it appeared together with an article by the «late» G. S. Oliver, as presenting the «soilution» thanks to a «hybrid domestic» earthworm. Obviously, this book, which refers to Darwin, contains a very astute commercial argumentation, which developed during the 40s on a deceptive base, favoured by the scientific deficiency of agricultural, pedological and zoological circles. First of all, Darwin in his 1881 book stressed the diversity of earthworms (pages 8 and 9) and pointed out the then existing taxonomic difficulties by restricting his work as follows: «We are here concerned only with the kinds which bring up earth to the surface in form of castings...» but he practically refers only to earthworms (lumbricids). While the French edition (1882) was introduced and protected from naivety by Perrier, the original English work attributes to the earthworms as a whole (in the above mentioned sentence) the results of a study that did not take into account taxonomy.

Astutely Barrett uses this confusion by alternating in a commercio-technical text, exact notes on the role of the earthworms, with the properties of «his domestic» earthworm. G. S. Oliver, in the role of a post mortem stooge (the late G.S.O., page 66) then served to valorise earthworms as active agents of the fertility of the soils (which is not wrong), but also as presumed authors of an «hybridization» of which we have a fairly smart report... Describing a «hybridization» done «after 1927» and described in detail in 1940 in a letter, which Barrett quotes in his book, the late G. S. Oliver gives in detail the hybridization of the dung-worm (*Eisenia foetida* Sav. = *Helodrilus foetidus* Barrett *Lumbricus terrestris* (L.)). After this apocryphal quotation, Barrett shrewdly distances him self from the topic: «This point is not highly important. The important point is that through his work of selective feeding and breeding, he did succeed in producing an earthworm with characteristics which answer perfectly all the requirements for intensive propagation and use.» (Barrett, op. cit. page 66). The «domesticated earthworm» is born, he is *perfectly* adapted to *all* the requirements for intensive propagation and use! ... This is not all, this exceptional animal eliminates Nature's complexity. «The original object of the experimental work which led to the development of the domesticated earthworm was to eliminate the element of change which are encountered in dealing with the exceedingly numerous varieties of native earthworms; ... (Barrett, op. cit.). Thus, Barrett-late Oliver gave birth to an exceptional earthworm (that one should buy!). The whole book is then built on exact quotations concerning the role of earthworms (anécics + endogeics on one hand, and, on the other hand, it provides the details of the breeding of a domesticated earthworm by in fact describing the classical breeding conditions used by earthwormbreeders): the epigeic dungworms become thus domesticated earthworms! The sale of these extraordinary, prolific worms to farmers for the improvement of the soil thus becames plausible... without any serious foundation,

but with the posthumous blessing of Darwin, and *even better*, of the grandfather of the late G. S. Oliver who *before Darwin* had already in 1830 recognized the importance of earthworms (Barrett, 1949, p. 45).

The book had been preceded by a Californian publication (Barrett, 1948) and probably other advertising announcements which I have not read. Published in London, it has had only feeble repercussions in Europe (Rohde, 1948; Brunnoli, 1967), it was strongly criticized by one of the rare qualified scientists in Europe (Wilcke, 1952), but it has been constantly used by the earthworm-breeders in the United States in order to enlarge their trade. Still today this swindle, based on the ignorance of the diversity of the species, of their needs and their roles, is transmitted by some wormbreeders whose commercialism goes greatly ahead of the technique.

Since then breeders have also given splendid as well as fanciful names to the «epigeics» of the litters of the vermiculture.

Indeed, the vermiculture is practiced empirically, wormbreeders do not know they breed... and very often in Europe and in the US, there are 2 or 3 species mixed together. In Europe the most frequent species in the south is *Eisenia andrei* Bouché 1972, and *Eisenia foetida* (Sav. 1826) in the north... with a frequent mixture of both. *Dendrobaena veneta veneta* (Rosa 1886), *Dendrobaena veneta hortensis* (Mich. 1889), *Dendrodrilus subrubicundus* (Eisen 1874) are still quite frequent. Very rare are *Lumbricus rubellus* (Hoff. 1845) (in advertisements often quoted by a literal translation as «red earthworm») ... *Eisenia eiseni* (Lev. 1884), *Dendrodrilus rubidus rubidus* ... (Sav. 1826), ecc. In warmer climates, *Eudrilus eugeniae* (Kimb. 1867) is also very common.

The work of Barrett reveals another situation ... the importance of «improved organic» matter in the context of the degradation of the soil.

The remarkable introduction by Eve B. Balfour presents a very clear problem in front of a topic that is still with us «Of the fertile cultivable area of the USA, as it was found by the pioneers, one-quarter has gone for ever, so their soil experts tell us, and many millions acres are still disappearing annually. The same story comes from South-Africa. Deserts can be seen there extending for hundreds of squares miles, that were producing good crops only thirty years ago...; those in authority are always preoccupied by the immediate problems of the moment that they become permanently myopic, and are literally incapable of taking any but the shortest of short-term views. At the present time, for example, the need for timber, for fuel and housing *now*, is of such apparently prime importance that it seems to justify the risk that a new desert will result to-morrow».

The confusion between the role of the earthworms in the field and that of the epigeics in a earthworm-compost, well maintained by Barrett (and by the

absence of an efficient scientific community) prompts the writer to retain the «prophetic» terms of Barrett.

«The problem facing civilization to-day is rebuilding the soil and restoring the earth to a form immediately usable for food production. By the slow process of nature, it takes 500 to 1.000 years to lay down an inch of topsoil. Under favourable conditions a task-force of earthworms can do the same job in five years. An individual working with a lug-box or a compost pile can start building topsoil for his garden. A farmer working with a manure pile can do it with his farm. A community utilizing a garbage dump can do it, or a nation working with its resources can do it».

During this same period a certain Ashmore, a New Zealand farmer, pratically created the direct use of earthworms... which was to be gradually improved. Barrett was unaware of this (the first publication appeared later: Nielson, 1951!). I shall take this point up again in section VI.

Likewise, certain serious studies tended to show that the epigeics played an effective role in the maturation of the (earthworm-) compost (Meyer, 1943; Anstett, 1951; Heitor et al., 1963...) but the results were not sufficiently extraordinary to interest Barrett.

The weak reply of Wilcke, who opposed in German, interspersed with Latin names, the intelligent, but dishonest demonstration of Barrett, was inadequate; it did not re-establish the effective potential tool that the earthworms represent; it did not prevent the growth in the USA of vermiculture based on the «Barrett model», where it has 4 outlets:

- bait the sale of which increased with leisure,
- the sale of soil ameliorators (essentially earthworm-compost of manure),
- the sale of books, pamphlets, and accessories of vermiculture,
- the sale of epigeics to «improve» the soil.

Thus, in vermiculture *à la Barrett*, there is an organized confusion of real properties and swindling.

4. The 70s: zoo-agricultural dissociation, energetic, proteic and environmental crisis

The evolution of the agrarian structure in the USA preceded that of Europe... but based on the same model the farms of the old continent gradually became specialized. At first, industrial monocultures without breeding or breeding without cultivation, then slowly breeding not dependent on the soil (farmers using complete industrially well-balanced food). With lower transportation costs,

the specialization of the exploitation came into being and the self-sufficiency of the farm disappeared.

Breeding outside the soil required increasing tons of complete food (fish-breeding, pig breeding, calves, chicken, rabbits, ...) and the waste of these industries (litter, excrete, urin) accumulated in nauseating, polluting masses (eutrophic action) was even toxic (copper of the pig litters, ...).

Parallelly, urbanization continued, individual consummation grew... the masses of food collected in rural districts left the cities as urban waste – liquid outflow of the sewers, heaps of rubbish mixed with packing material stemming from cleared forests (paper, cartoon), from fossil carbon (plastics), or from energetic-mineral sources (glass, ...) –.

The ecologistic reaction (ecologism = socio-political movement, not to be confused with ecology = science) and the energy crisis competed to hasten the «realization» of the 70s.

In an attempt to justify the earthworm industry a small work (McInroy, 1971) focused attention on earthworms as a protein source.

Then Graff (1974) studied the feasibility of earthworm production departing from an agricultural basis.

The environmental crisis turned the attention to the treatment of waste: the NSF (National Science Foundation), USA, as well as local authorities confronted with the problem of the disposal of sludge, and the French Ministry for the Environment, newly created (1972), (Commision for Soil and Solid) in an attempt to eliminate the rubbish and sludge, investigated ways to use waste, including organic waste. Two reports appeared simultaneously, one on the sludges (Hartenstein and Mitchell, 1977, unpublished), the other on the exploitation of waste and sludges (Bouché, 1977, published in 1979). In the first case, vermiculture was linked to the problem of the treatment of sludge... in the second, an earthworm specialist tried to tackle the problems of protein-production and of the exploitation of waste (rubbish, sludge, industrial waste).

The American team has published numerous articles, while research in France has focused on breeding conditions, on the nature of treatable waste (Fayolle, 1982), and on the nature of earthworm produced (Chaudonneret, 1977), as in Germany (Schutz and Graff, 1977). In Japan (Watanabe et al., 1976), described the spontaneous populations of *Eisenia fetida* in compost, which was used intentionally in France (de Blignières, 1980). Thus, very slowly, a body of knowledge was assembled on the possibilities offered by earthworms in organic waste, their needs for breeding, their composition of proteins, and fatty acids and pollutants. The quality of the organic matter so obtained, which was already perceived in 1943 (Meyer), remained however misunderstood because of the very gross character of the reproduceable technical assessments that were made

regarding a diversity of products and a variety of demands. In 1979 Mary Appelhof tried to popularise the individual earthworm composting of organic waste, whereas the vermiculture *à la Barrett* made the tour around the world and, above all, via Italy started to sweep Europe.

5. The 70s, 80s turning point: The actors meet

At this time earthworm breeders and «scientists» had gone along with each other, not always easily. The need to do business in order to prosper or to hold one's own on the one hand, and a not always adequate technical ability on the other rendered exchanges between the two sections difficult.

However, apart from a few spectacular contrasts, there was a mutual will to cooperate. Although certain errors propagated by earthworm breeders and denounced by scientists disappeared from most of the publications, earthworm breeders quickly understood the importance environmental topics would have in the creation of new outlets. Firms are trying to standardize their techniques by letting them develop on new substrats, while some scientists are becoming more aware of the concrete restraints of practical applications.

Thus, in the best cases, a more suitable language was used. Vermiculture discredited itself through advertising misuses, but the more serious earthworm breeders understood this, and as earthworm production become more viable, a more concrete approach took shape. Of course, this does not apply to neither all earthworm breeders, nor to all «scientists»: many advertising pamphlets based on a vermiculture à la Barrett used a pseudo-scientific style laced with fanciful Latin names, or ridiculous as well as incorrect details (the worm from «California» has a temperature of 19° C, it has 5 hearts, 6 kidneys, ...!).

On the opposite side, the excesses of an improper and deceiving trade led certain scientists to charge vermiculture with such risks as epidemics frequently described but never scientifically controlled (not to be confused with accidents due to a physical lack of ventilation, or with individual, not epidemic illnesses: Heimpel, 1966; Heitor, 1978). The repetition of such disinformation through the mass media (newspapers, TV, ...) on the lookout for the sensational did not help at all.

On the other hand appreciable progress has been made, concepts such as the ecological categories (the earthworms were divided in three categories: epigeics, endogeics, anecics) allowed the exchange of technical information. They avoided difficult Latin names and delicate definitions that require considerable practice in a still unstable nomenclature (see in Bouché, 1972, «La double nomenclature»). The concept directly related to the roles of the animals, favoured distinctions and

invalidated the arguments unfortunately introduced by Barrett-late Oliver, in addition it also supported the illusion of the omnipotent role of a single earthworm for the fertility of the soil of great cultivations. Large-scale tests, mainly on the pig (Sabine, 1983) tended to prove the feasability of earthworm breeding not only for vermicomposting, but also for industrial vermiculture.

Other actors enter the scene: industries and communities. The communities have to treat increasing volumes of waste, and due to the lack of convenient or really satisfactory methods of treatments the societies or enterprises charged with the elimination of waste turned towards the earthworm. It is remarkable that it was the frequently cranky advertising of earthworm breeders that attracted the attention of industrialists who then tried to exploit departing from a serious, more scientific base, the products to be treated. This led to the first colloquium in the USA, where scientists and breeders exchanged their views (Appelhof, 1981). In France, where the earthworm-biotechnology was not developed through research channels, because of a lack of awareness of the problems in question, it was this process that provided the first satisfactory refining of difficult fatty sludges (Milhau et al., in print) and the first encouraging results on rubbish (Heidet, in preparation). The support of the authorities was limited to the diffusion of information, on an international level (International Union of Local Authorities, Bouché, 1982) and in the USA (Appelhof, 1981), in France (Anonymous, 1983) etc., on a national level.

This led to an awareness of the complexity of a similar vast area. It is impossible to approach on the same technical and commercial level the exploitation of a variable product such as manure for vermicompost, elimination of rubbish, production of proteins, treatment of contaminated waste. Thus, Great Britain, which showed an interest in this topic only in 1980 (Edwards, 1983) took a clear option: to obtain earthworm-flour for food supplements of zootechnical farms (mostly fish breeding) departing from agricultural organic waste (not contaminated).

The tools existed, not only was it possible to accurately recognise species, but also could the tests for toxicity, and above all bioaccumulations could be precisely determined (Bouché, 1984 a and b). Earthworms may become a direct means to evaluate the bioavailability of contaminants in the soils.

6. The other biotechnology: biostimulation

Let us be clear: the earthworms suitable for vermiculture (production of baits or zootechnical food) and for vermicomposting (treatment of organic matter) are the epigeics? (Bouché, 1971): despite repeated attempts, they did not play

any important direct role in the fields until recently (Southwell et al., 1982).

Inversely, the earthworms working in the organo-mineral soil are the «anecics» (in temperate areas of the old continent) and the «endogeics» (everywhere). These animals of modest demography do not land themselves to intensive (and probably useless) breeding, but present a remarkable variety of still badly known taxons. Their role, already well perceived by Darwin is starting to be well evaluated: they play a major part in agrosystems (Bouché, in preparation 1). The consequences resulting from the involuntary introduction of European lumbricidae have been described by Ashmore (in Nielson, 1951) in New Zealand, as well as by Langmaid (1964) in Canada. Only the observations of the former have been evaluated by systematic introductions (Stockdill, 1966) of animals not necessarily the most efficacious that chance has provided the technician with.

The equivalent Soviet approach (Ghilarov and Mamajov, 1967; Ghilarov and Perel, 1984) is also very pragmatic as is that of Marshall (in print) who has tried everything (including Australian «endogeics») but has succeeded in the end with local stocks.

Today, however, we have the beginnings of strict disciplines to aid in the selection of species according to the desired roles (morphofunctional studies by ecological categories), and of the environments in which to introduce them (mesological knowledge, Bouché, 1972 today managed by computer), moreover, it is possible to simulate the economic and technical effects thanks to forecasting models (Bouché, in preparation).

The first results obtained on this basis (Trehen and Bouché, 1973) proved to be encouraging (Brun et al., in preparation), but have shown the need to better delimit the influence of climatic and/or seasonal variables (Heidet, in preparation), which is today better understood (Heidet and Bouchée, in print). The use of this potential within the framework of agrotechnical units seems to have a very important promising future (Bouché, in preparation 2). It is hardly probable that such introductions can be based on the breeding of special strains that will not be very productive, when the natural populations assure a spontaneous «overproduction». Biostimulation and vermicomposting are two totally different techniques both because of their effects and because of the species used.

7. Towards a viable economic diversity of vermitechnologies

Vermiculture and vermicomposting form a unit because of the use of «epigés», however the substrata used and the objectives can, as we have seen, be very different. Two contradictory errors have to be avoided:

- to envisage only a technico-economical objective, excluding all other considerations;
- to envisage all the technico-economical objectives without selecting priorities.

To schematize, let us list the uses of earthworms.

1) Production of bait through vermiculture.
2) Production of food for animals (constitutive flour for zoo-technical use) through vermiculture.
3) Production of vermicompost through vermicomposting.
4) Elimination of organic waste through vermicomposting.
5) Survey of contaminants through biosampling.
6) Protection and management of natural populations in the field.
7) Reasonable introduction (or not) of earthworms to biostimulate the soil.

Points 1, 2, 3, 4, 5 concern vermiculture-vermicomposting (use of «epigeics»), points 5, 6, 7 concern the farming practices directly usable in the field (above all «anecics» and «endogeics»). Only point 5 regards both groups of biotechnologies.

These first 5 points (Fig. 1) are closely linked on certain levels. One does not practice vermiculture without vermicomposting; one should not commercialize a vermicompost or earthworms without knowing their possible contamination, etc. In practice the situation is quite different.

One conceives rather well that the production of bait can be lucrative and that waste disposal can sometimes be assured by familial vermicomposting: this is the individual or microcraft scale.

One realizes also that the ever more generalized practices of farming without

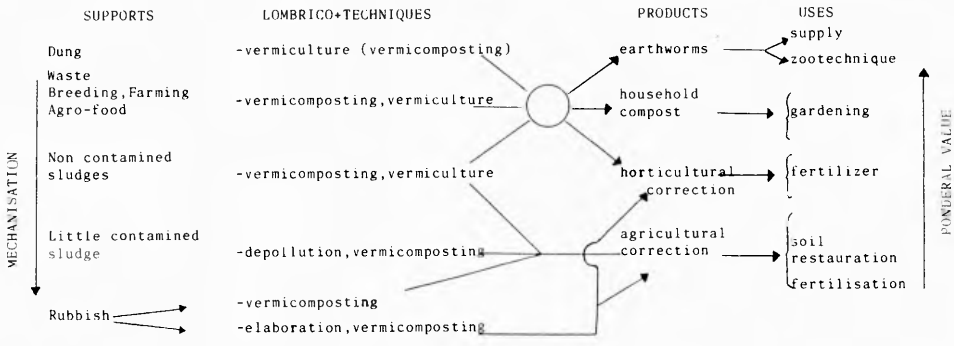

Fig. 1 - Vermi-techniques of treatment and exploitation of organic matter. In general the products of decreasing weight require increasing engineering (mechanisation). In all cases, the products should be evaluated for contaminants.

breeding (vast industrial cultivations of wheat, potatoes, beetroots, ...) and breeding without agriculture leads to an inadequate exploiting.

Vermicomposting on the farm can perhaps constitute a future way, particularly since the horticulture of luxury products (ornamental plants, ...) develops in parallel to domestic customs and it requires quality organic matter. An evaluation of high quality products would also be possible, but it implies a technical definition of the latter which largely exceeds the actual norms and the techniques of usual assessment. The reliable studies on organic matter are widely lacking here.

Vermicomposting of «high scale» products can be conceived on the craft or industrial scale.

On the other hand, it is not to be doubted that the industrial level will be indispensable in the majority of cases concerning sludge and rubbish, but that the interest of these projects will vary according to technical constraints, such as the presence of inert material (glass, plastics, ...) in the rubbish or the contamination of the products (point 5).

It may be profitable *in itself* to reach first one of these 5 objectives, but very often one of the two or three other associated points bring an additional income.

Industrialisation is in progress, the mechanisms used, often directly derived from the «in litter» technique, will be further developed and will probably lead to the use of more or less specialised material. Thus one sees (at last!) technological studies on earthworm flour, from its extraction to its processing (English studies of BET, Cambridge College, 1984). Mechanisation of breeding in litter can be envisaged in countries where the climate indicates that this formula may be maintained and improved (Italy..).

The integration of vermicomposting into the process of formation, collecting, treatment, evaluation and elimination of waste is finally in progress. In the latter case, vermi-technology is part of a much larger whole, but it is a decisive element for the success of this whole.

However, there are major obstacles to the progress of this field: the paucity of serious earthworm studies, and its corollary, the rareness of competent specialists. The anachronistic situation of our concretly appliable knowledge on organic matter, the needs of which are, in addition, very varied, and the weakness of studies in relation to anorganics and toxics tend to downgrade (Bouché, in print) to commercial level vermicomposts and to hold back a boom in this field. Lastly, serious engineering studies are scarce.

The development of vermitechnologies will assure the economic success of the above-quoted points, but, vice versa, this success requires investments in these biotechnologies... As long as one does not consider vermicomposting and vermiculture as a panacea, the first successes encourage optimism. In any case, to reduce to a single question (as do certain technocrates or naive industrialists: is

vermiculture profitable?), to condemn this activity with a particular argument or to consider this practice as a definite success, is in all cases evidence of an ignorance of economical problems, horticultural techniques, agricultural evolution, environment and underlying techniques: there is an enormous diversity of situations, each of which needs a special answer.

REFERENCES

Anonyme, 1983 – Le lombricompostage. Compost-information, *11*, 1-36.

Anstett A., 1951 – Sur l'activité macrobiologique des phénomènes d'humidification. C.R. Acad. Agric., *37*, 262-264.

Appelhof M., 1979 – Small solutions help solve great problems. Kalamazoo gazette viewpoint, page A-7.

Appelhof M., 1981 – (compiled by) – Workshop on the rôle of earthworms in the stabilization of organic residues. I. Proc. Kalamazoo, Michigan, April 9-12 1980, 1-315.

Bouché M. B., 1982 – Les lombriciens et le traitement des déchets. Lumbrici and the treatment of waste. IULA Newsletter, *3*, 1-2.

Bouché M. B., 1983 – The establishment of earthworm communities. *In* J. E. Satchell (Ed.) «Earthworm ecology from Darwin to vermiculture». Chapmann et Hall, London, *8*, 431-448.

Bouché M. B., 1984a – Ecotoxicologie des lombriciens. I. Ecotoxicité contrôlée. Oecol. applic., *5*, 271-287.

Bouché M. B., 1984b – Ecotoxicologie des lombriciens. II. Surveillance de la contamination des milieux. Oecol. applic., *5*, 291-301.

Bouché M. B.,Ferrière G., Soto P., 1987 – The role of earthworms in the decomposition and nitrogen nutrition of plants in a. grassland. This volume, 113-129.

Bouché M. B., in preparation – Prairies et vers de terre: un potentiel de progrès insoupçonné.

Brun J. J., in preparation – Etude de la régulation hygrothermique et photopériodique de l'activité lombricienne, et perspectives d'applications pour biostimulation des sols. Thèse 3ème cycle, USTL Montpellier.

Brunnoli A., 1967 – L'allevamento del lombrico. Edagricole Ed., Bologna.

Chaudonneret M. B., 1977 – Quelques données sur la composition biochimique des vers de terre, aliments éventuels du bétail et de l'homme. Rapport de stage, fin d'étude INSA, Lyon, 1-37.

Darwin C. R., 1881 – The formation of vegetable mould through the action of worms with observations on their habits. John Murray and Co. Eds., London, 1-326.

Darwin C. R., 1882 (traduction française de Darwin, 1881) – Rôle des vers de terre dans la formation de la terre végétale. Reinwal, Ed. Paris, 1-257.

Edwards C. A., 1983 – Earthworms, organic waste and food. SPAN, *26*, 106-108.

Fayolle L., 1982 – Etude de l'évolution du système déchets-lombriciens-microorganismes: perspectives appliquées. Thèse doct.-ing. Univ. Cl. Bernard Lyon (12/03/82), 1-130.

Ghilarov M. S., B. M. Mamajev, 1967 – Das Einsetzen von Regenwürmern (Oligochaeta Lumbricidae) in die Böden artesisch bewässerten Oasen als Massnhame zur Steigerung des biologischen Aktivität. *In* O. Graff & J. E. Satchell «Progress in soil biology». North Holland publ. co. Amsterdam, 275-281.

Ghilarov M. S., T. S. Perel, 1984 – Transfer of earthworms (Lumbricidae) (Oligochaeta) for soil amelioration in the USSR. Pedobiologia, *27*, 107-113.

Graff O., 1974 – Gewinnung von Biomasse aus Abfallstoffen durch Kultur des Kompostregenwurms *Eisenia foetida* (Savigny 1826). Landbauforsch. Völkenrode, *24*, 137-142.

Hartenstein R., Mitchell M. J., 1977 – Interim report – Utilisation of soil invertebrates in stabilization, decontamination and detoxification of residual sludges for treatment of wastewater. (report NSF-RANN. Grant n° ENV76-17225).

Heimpel A. K., 1966 – A crystalliferous bacterium associated with a «blister disease» in the earthworm *Eisenia foetida* (Savigny), Invert. Pathol., *8*, 295-298.

Heitor F. P. C., M. A. Soares Ribeiro, 1963 – O papel da *Eisenia foetida* Sav. (Oligochaeta, Lumbricidae) na decomposiçao da palha de aveia para obtençao de estrume. Agron. lusit., *25*, 829-837.

Heitor F., Boemare N., Amargier A., 1978 – Mise en évidence d'une infection bactérienne chez le ver de terre. (Bactériose chez les vers de terre). Ann. Zool. – Ecol. anim., *10*, 507-514.

Langmaid K. K., 1964 – Some effects of eathworm invasion in virgin podzols. Can. J. soil sci., *44*, 34-37.

Marshall B., in print – Improvement of Scottish hill pasture by earthworms, clover and lime. In Proc. Int. Conf. on Earthworms, Waste Environ. Management. Cambridge (23-27/07/1984).

Mc Inroy D. M., 1971 – Evaluation of the earthworm «*Eisenia foetida*» as food for man and domestic animals. Feedstuffs, *43*, 46-47.

Meyer L., 1943 – Experimenteller Beitrag zur makrobiologischen Wirkung auf Humus und Bodenbildung. Bodenk. u. Pflanzernähr., *29*, 119-139.

Milhau C., Vignoles M., in print - Treatment of fat and other floating waste: one solution: vermicomposting. Proc. Int. Conf. Earthworm Waste and Environ. Management, Cambridge (23/07/1984).

Nielson R. L., 1951 – Earthworms and soil fertility. Proc. 13th Conf. NZ Grassl. Assoc. New Plymouth, 158-167.

Oliver G. S., 1949 – Our friend the earthworm. Gardener's book club, 8.

Rohde G., 1948 – Fortschritte in der Kompostbereitung. Deutsch. Landwirts., *2*, 172-173.

Sabine J. R., 1983 – Earthworms as a source of food and drugs. In J. E. Satchell (Ed.) «Earthworm ecology from Darwin to vermiculture». Chapmann and Hall, 285-296.

Schulz E., Graff O., 1977 – Zur Bewertung von Regenwurmmehl aus *Eisenia foetida* (Savigny 1826) als Eiweisfuttermittel. Landforsch. Völkenrode, *27*, 216-218.

Southwell L. T., Majer J. D., 1982 – The survival and growth of the earthworm *Eisenia foetida* (Lumbricidae, Oligochaeta) in alkaline residues associated with the bauxite refining process. Pedobiologia, *23*, 42-52.

Stockdill S. M. J., 1966 – The effect of earthworms on pastures. Proc. N. Z. Ecol. Soc., *13*, 68-74.

Trehen P., Bouché M. B., 1983 – Place des lombriciens dans les processus de restructuration des sols de landes. *In* P. Lebrun et al., «New trends in soil biology», CR VIIIème Coll. int. zool. sol, Louvain la Neuve, (Belgique), 30 août-2 sept. 1982, 471-486.

Watanabe H., Tsukamoto J., 1976 – Seasonal change in size and stage structure of Lumbricid *Eisenia foetida* population in a field compost and its pratical applications as the decomposer of organic waste matter. Rev. écol. biol. sol, *13*, 141-146.

Wilcke P. E., 1952 – Zur «Domestikation» des «Soilution - Earthworm». Anz. f. Schädlingskd., *25*, 107-109.

MARCEL B. BOUCHÉ
Laboratoire de Zooécologie du Sol,
CEPE INRA/CNRS, BP 5051 F-34033
MONTPELLIER Cédex (FRANCE)