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Addition of earthworms to soils in soil ecological field experiments

Kevin R. Butt[1]

Abstract
Over recent decades experiments have been undertaken to reveal the optimum method for introducing earthworms into soils so the animals have greater chances of survival and are able to produce sustainable populations. This article describes development of the Earthworm Inoculation Unit (EIU) technique, its advantages over more traditional introduction methods and how it has been used. EIUs provide the means for sustainable earthworm population development even under harsh soil conditions, such as restored sites. However, certain circumstances dictate that this technique is not appropriate as digging in the soil/turf is unacceptable. Here more traditional methods can still be of value.
Keywords: earthworm, soil, inoculation

Introduction:

Earthworms are normally introduced into soils where they are absent either to utilize their natural burrowing/casting activities and hence assist rehabilitation of soil properties or to provide a food source for other organisms through re-establishment of lost links in food webs.

A number of methods have been used of which collection and broadcasting is perhaps the most obvious, although cutting of earthworm-rich turfs has also been employed. The technique described here was developed to try and take the beneficial aspect of these existing methods and equally avoid the less attractive elements of each. To this end, the Earthworm Inoculation Unit (EIU) technique was developed.

The EIU technique has two phases, the first involves cultivation and the second is soil-inoculation. Cultivation requires a starter culture of mature animals which are kept within a plastic envelope (bag) filled with soil and an appropriate (for the species) food source. This forms the EIU which is then housed under optimal conditions for reproduction over a prescribed period (e.g. 3 months over summer or winter). During this phase the temperature can be maintained by under soil heating and soil moisture content by sealing the unit except for small pin-sized holes. The adult earthworms of the starter culture should mate, and produce cocoons. If density is set at an optimum level for unit size, maximum reproduction can be encouraged. Therefore at the end of the cultivation phase, the minimum contents of the unit will be adults and the cocoons they have produced, with the possibility that some hatchlings may also be present if the earthworm species used reproduced rapidly, thereby presenting all 3 life stages. The EIUs are then ready for the soil-inoculation phase.

The inoculation phase involves transportation of the EIUs to the desires inoculation site. Holes need to be drilled/dug (the size of the EIU) in preparation for use. These are spaced

[1] University of Central Lancashire, Preston, PR1 2HE, United Kingdom. Email: krbutt@uclan.ac.uk

according to required initial field density. Inoculation involves removal (cutting) of the plastic envelop and insertion of the contents of the EIU into the prepared hole. Care should be taken to ensure that the contents remain as a unit and are inserted vertically as cultivated. This ensures the greatest chance of successful colonization of the site by the enclosed earthworms as they are least disturbed at inoculation and cocoons remain at the depth produced. As a number of life stages are introduced to the site, survival and ultimately growth of the population is enhanced.

Industrial Site Case Studies:
Calvert
The first trial of this technique employed 4 litre EIUs provisioned with 6 mature *Lumbricus terrestris*. These were fed paper pulp and yeast extract over a period of 6 months. Inoculation in 1991 was at Calvert landfill site in southern England, into deliberately compacted clay (b.d. 1.6 to 2.0 g cm^{-2}). Results from this trial were disappointing, but this was deemed to be a function of the species chosen (not suited to such soils) – but desired by the site managers – against advice of the researchers. A subsequent trial at the same site used *Aporrectodea longa* and *Allolobophora chlorotica* in 2 litre EIUs, in monoculture and also mixed culture. These were fed cattle manure and cultured for 3 months. Reproduction within the EIUs was high giving rise to larger field starter cultures. Subsequent field results were positive with greater survival and spread over years (Butt et al 1997). Movement of *A. longa*, determined from cast observation, was less than 3 m y^{-1} through the clay, over the first 5 years but animals had spread up to 130 m after 10 years. Use of appropriate species was critical for success and the combination of an endogeic and an anecic species led to positive interactions. A smaller EIU volume also permitted greater ease of handling at time of inoculation. This smaller size is now seen as “standard” by the author.

A further ongoing trial utilized *A. longa, A. caliginosa* and *O. cyaneum* in all combinations with a large input of food in the form of composted green waste. Absence of organic matter at this site had previously been determined as one of the limiting factors in earthworm community development (Butt et al, 2004).

Hallside
A disused steelworks site at Hallside near Glasgow, in Scotland saw a further application of the EIU technique in 1996. Reported by Bain et al. (1999), this trial was beset with numerous problems and did not assist in promoting further use. Poor quality “soil” – colliery spoil – was mixed with sewage sludge, with purchased *L. terrestris* as the starter culture. Coupled with poor field-inoculation (by inexperienced labourers), results suggested that very few, if any, of the earthworms survived, and little reproduction had occurred within the EIUs.

Agro-ecosystem Case studies:
A trial of the EIU technique at Coshocton in the USA attempted to introduce *L. terrestris* into a watershed where it was absent, even though this species was present in close proximity within this landscape. This exercise proved to be unsuccessful (Butt et al. 1999) but was attributed to soil water properties and not a failing of the technique.

An attempt was also made in Finland to encourage *L. terrestris* to colonize a heavy clay field from which it was previously absent. Here EIUs were inoculated into the field margin and then monitored after a period of 7 years (Nuutinen et al. 2006). Field conditions were also improved by subdrainage and the implementation of reduced tillage. Results suggested that here the species has begun to gain a foothold in the agricultural soils (migrating in at 1.1 m y^{-1}) and it is hoped will assist in soil amelioration. This work is ongoing.

Uses of Traditional Inoculation:

There are occasions when a technique such as the EIU can be inappropriate. Certain field locations are not conducive to being dug and having an alien substrate added. One such example is a training ground for racehorses (gallops) in the south east of England. Here the whole landscape had been re-profiled to create ideal race conditions, but this involved total soil removal, storage and reinstatement. In these processes all earthworms appeared to have been killed. Therefore inoculation of earthworms was desired, but due to the careful recreation of laser-leveled profiles, use of the EIU technique was outlawed. Also "false ground" at the point of inoculation might have led to missed footing and potential injury to the valuable horses. An alternative option was found. This was to collect earthworms from a local undisturbed site (by plough-following) and introduce them into the slots created by "verti-draining" the gallops. The outcomes of this procedure will be monitored from this ongoing project.

Another location where a more traditional technique was appropriate for inoculation was at Manchester Airport. When a second runway was built in 1998, floristically-rich (and earthworm-rich) turf was translocated to areas away from the site of runway construction. When re-laid it was found to connect with the subsoil on to which it was placed.

Monitoring over time (Butt et al, 2003) has shown that earthworm communities are sustainable and are providing a food source for some of the legally protected animals on site (such as *Meles meles* and *Triturus cristatus*).

Other areas where introduction of earthworms using a more traditional (broadcast) method are appropriate include experimental situations. For example, Grigoropoulou (2009) examined the effects of *L. terrestris* density on the settlement and dispersal of this species. Within 1 m^2 fenced arenas in the field, she manipulated density by direct addition of adult animals at the soil surface. No other type of earthworm addition would have been appropriate here as burrows and their earthworm occupiers, within the arena, had to remain undisturbed so as not to compromise the experiment.

Conclusions

Introduction of earthworms into soils should only be undertaken when a number of factors have been established. Questions to be asked include: Is there good reason for inoculation (will natural colonization occur)? If used, which method would be best? Which species would be appropriate? Where would the earthworms be sourced? Would a mixture of species/life stages be best? Would sufficient organic matter be present? How and when would monitoring be undertaken? Does the cost warrant all of this?

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