# Agronomy Guide

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# Earthworms and Crop Management

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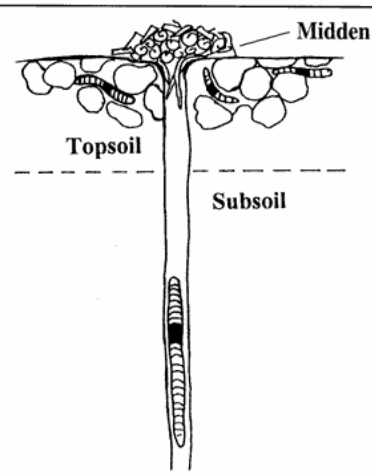
Earthworms have long been associated with healthy, productive soils. In his 1881 book entitled "The Formation of Vegetable Mould through the Action of Worms," the great biologist Charles Darwin stated that, "It may be doubted whether there are many other animals which have played so important a part in the history of the world, as have these lowly, organized creatures." Although earthworms are known to be beneficial to soils, their degree of importance in different agricultural systems is poorly understood. This publication provides basic information on earthworm ecology, the effects of earthworms on soil properties and processes, and the influence of soil management practices on earthworms. It concludes with a section on how to encourage the buildup of earthworm populations in agricultural fields, as well as some remaining questions that require further study.

Figure 1.




## General Ecology

There are thousands of species of earthworms in the world. Those that live in the soil can generally be grouped into three major behavioral classes: the litter-dwellers, shallow soil dwellers, and deep-burrowers. The litter-dwelling species live in the litter layer of a forest, for example, and are generally absent from agricultural fields. Typical agricultural fields may have one to five different shallow-dwelling species and perhaps one deep-burrowing species.

The deep-burrowers ("nightcrawlers") build large, vertical, permanent burrows that may extend 5 to 6 feet deep or more. They pull plant residues down into the mouth of their burrow, where the residues soften and can be eaten at a later time. Nightcrawlers construct *middens* over the mouth of their burrows. Middens are a mixture of plant residues and castings (worm feces) and probably serve as protection as well as a food reserve. Because nightcrawlers require residues at the surface to pull down into their burrows, we do not expect to find any nightcrawlers in fields which routinely leave no surface residue cover (i.e. moldboard-plowed). The species of nightcrawler in the north-central region is *Lumbricus terrestris*. The length of adult nightcrawlers is usually 4 to 8 inches or more.

The shallow-dwelling worms (known as redworms, grayworms, fishworms, and many other names) are comprised of many species that live primarily in the top 12 inches of soil. Adult length is usually 3 to 5 inches. They do not build permanent burrows, but instead they randomly burrow throughout the topsoil, ingesting residues and mineral soil as they go. Because they do not require residues at the surface specifically, we do not expect them to be as sensitive to residue management as are the nightcrawlers. However, they are affected by the amount of surface mulch because of the impact on soil temperature and moisture extremes. This is discussed in more detail in the section on tillage.

Earthworms are seasonal in their activity. The shallow-dwellers are active in spring and fall but generally enter a resting state in summer and winter. As the soil starts to heat up and dry out in late spring (typically May in the North Central states), the shallow-dwellers move a little deeper (perhaps 18 inches), curl up in a ball, and secrete a mucus to try to keep from drying out. They spend most of the summer in that state. In fall, when the soil starts to cool and become wetter, they become active again, but then often enter into a hibernation state for the winter. The nightcrawlers also tend to be more active in spring and fall, but they may not go into a complete resting state in summer or winter since they can retreat to the bottom of their burrows during extremes of heat or cold. The best time to observe or count earthworm populations is early- to mid-spring (often April in North Central states), or late fall (November).

Earthworms have both male and female sexual organs. Most species require a partner for mating. During mating, sperm are exchanged and stored in one of the segments of the worm. The cocoon casing is then produced by the *clitellum* (the band seen on mature worms), and the worm "backs out" of the casing, depositing the sperm and eggs into the casing as it passes over the appropriate segments. The cocoon (2-4 mm in diameter) then incubates in the soil for several months, depending on soil conditions, before one young worm (or two for some species) emerges. New worms will generally only emerge when soil moisture and temperature conditions are suitable.

## Effects on Soil Properties

The degree of importance of earthworms in maintaining soil and crop productivity will vary depending on circumstances. Earthworms are almost always beneficial, when present, but they may not be necessary. Some soils can be very productive without the presence of earthworms. The worms have sometimes been shown to improve crop growth and yield directly, but more often their activity affects crop growth indirectly through their effects on soil tilth and drainage.

Earthworms can have significant impacts on soil properties and processes through their feeding, casting, and burrowing activity. The worms create channels in the soil, which can aid water and air flow as well as root development. The shallow-dwelling worms create numerous small channels throughout the topsoil, which increases overall porosity and can help improve water and air relationships. Nightcrawlers create large vertical channels, which can greatly increase water infiltration under very intense rainfall or ponded conditions. Nightcrawler channels can also aid root proliferation in the subsoil, due both to the ease of root growth in a pre-formed channel and the higher nutrient availability in the cast material that lines portions of the burrow. Earthworm casts, in general, are higher in available nutrients than the surrounding mineral soil, because the organic materials have been partially decomposed during passage through the earthworm gut, converting the organic nutrients to more available forms.

Earthworms improve soil structure and tilth. Their casts are an intimate mixture of organic material and mineral soil and are quite stable after initial drying. The burrowing action of the worms moves soil particles closer together near burrow walls, and the mucus secreted by the worms as they burrow can also help bind the soil particles together. Increased porosity, plus mixing of residues and soil, are additional ways that earthworms improve soil structure.

The mixing of organic materials and nutrients in the soil by earthworms may be an important benefit of earthworms in reduced tillage systems, especially no-till. The earthworms may, in effect, partially replace the work of tillage implements in mixing materials and making them available for subsequent crops. In *natural* ecosystems such as forests, organisms recycle last year's leaf litter into the soil for release of nutrients. With no-till planting we may also depend more on earthworms and other soil organisms to do this mixing for us. It seems appropriate, therefore, to try to determine how we can manage soils to encourage the organisms and their activity.

## Management Impacts on Earthworms

When we manage soils for crop production, we are also managing the habitat in which earthworms and other organisms live. Management practices affect earthworm populations by affecting food supply (location, quality, quantity), mulch protection (affects soil water and temperature), and chemical environment (fertilizers and pesticides). By considering how these factors are changed in different management systems, we can often predict the general effects on earthworm populations for systems that have not been studied.

Productive pasture fields will usually have much higher earthworm populations than row-cropped fields, primarily because of the large amounts of organic materials that are continually being added to the soil. Continuous root growth and subsequent death and decay, plus animal manure, provide a large food supply that can maintain high earthworm populations. In addition, the pasture plants act as a mulch to buffer the soil against rapid changes in temperature. Pasture fields are also not usually tilled, and thus burrow systems are left undisturbed.

Within row-cropping systems, using tillage systems which leave surface residue, is one of the most important ways that earthworm populations can be influenced. No-till systems usually have higher earthworm populations than do conventional moldboard plow systems, due to increased food supply and mulch protection. With residues on the soil surface, the food supply is available to the earthworms for a longer time than if residues are incorporated with a tillage implement. In addition, the surface residues act as a mulch and slow the rate of soil drying in late spring and freezing in late fall. This can lengthen the active periods for the worms, allowing them to feed and reproduce a little longer in both spring and fall. Surface residue also gives the earthworms more time to acclimate to the summer or winter and move down into their resting state. No-till is even more important for nightcrawlers than for the shallow-dwelling worms. Because nightcrawlers feed primarily on residues at the surface, pulling them into their permanent burrows, a clean-till system is not very conducive to nightcrawlers. The surface food supply is not present in plowed soils, and the top portion of the permanent burrow must be reformed after any tillage operation. Although a few nightcrawlers may be present in plowed fields, often they will not be present at all.

Tillage systems that are intermediate between the extremes of moldboard plowing and no-till will tend to have intermediate populations. The amount of surface residue cover is the key factor to consider when assessing different possible tillage practices for a field, as well as establishing conditions which encourage earthworm populations.

Data collected in Indiana and Illinois over the past 10 years confirms the generalizations just discussed. Earthworm populations were counted after 10 years of tillage plot history on a dark, poorly-drained silty clay loam soil near West Lafayette (Table 1). Very few worms were found in the continuous corn plots under either plow or no-till, and there were no statistically significant differences between the two treatments. Populations were surprisingly low and may have been affected by drought conditions the summer before the survey.

The continuous soybean plots had higher populations than continuous corn, with no-till having more than twice the worm population that moldboard plowing had. Earthworms generally prefer legumes as a food source over grasses, and this is probably the main reason for the higher populations found in the soybean plots. The continuous corn plots also received applications of corn rootworm insecticide and anhydrous ammonia, both of which can kill some earthworms. However, the effect of these chemicals on overall field populations of worms is probably small. Ammonia will kill a few worms right in the zone where it is injected, but some limited observations and counts before and after injection have suggested that less than 10% of the population is affected. Likewise, some corn rootworm insecticides kill earthworms, as can be seen by dead earthworms at the soil surface over the seed row. The overall effect on field populations is probably small, however, as long as the material is banded or in-furrow so that only a small zone of soil is affected. A rotation of corn and soybeans will generally have higher earthworm populations than continuous corn, probably due in part to elimination of the rootworm insecticide use, but mainly due to inclusion of a legume in the system.

Earthworm populations were much higher in a pasture than in the row-cropped fields (Table 1). Where the manure of the grazing animals was augmented by heavy applications of manure from the barnyard, populations were very high. Animal manures, sewage sludges, and other organic wastes will usually help build earthworm populations, although there may be an initial detrimental effect if there is a high concentration of ammonia in a slurry material.

Data from a poorly drained silt loam soil, low in organic matter, in southeastern Indiana illustrates some intermediate tillage practice effects as well as

**Table 1. Earthworm populations on silty clay loam soil near West Lafayette, IN.**

| Crop[a] | Management[a] | Earthworms/$m^2$ |
|---|---|---|
| Cont. corn | Plow | 10 |
| Cont. corn | No-till | 20 |
| Cont. soybeans | Plow | 60 |
| Cont. soybeans | No-till | 140 |
| Bluegrass-Clover | Alleyway | 400 |
| Dairy pasture | Manure | 340 |
| Dairy pasture | Manure (heavy) | 1300 |

[a]Crop and management systems had been continuous for at least 10 years.

**Table 2. Earthworm populations (April) under corn-soybean rotation on silt loam soil in southeastern IN.**

| Tillage | Earthworms/m2 | | |
|---|---|---|---|
| | 1987 | 1988 | 1989 |
| Chisel | — | 44 | 67 |
| Ridge-till | — | 189 | 178 |
| No-till | 156 | 133 | 211 |

year-to-year variations (Table 2). Earthworm populations were counted in spring in a corn-soybean rotation. The fall chisel system had less worms than either ridge-till or no-till, due to much less residue cover. Ridge-till and no-till populations were comparable, with ridge-till having slightly more worms in 1988 and no-till slightly higher in 1989. *Populations will vary from year to year as well as within a year, due to weather conditions and food availability.* There were no nightcrawlers present in any of these plots.

In April 1992 earthworm populations were surveyed on 14 pairs of farmers' fields in central Indiana and Illinois. Each pair consisted of a no-till and tilled (usually chiseled) field on the same soil type, in a corn-soybean rotation, as close together as possible (usually less than 1 mile apart). Most of the no-till fields had been in no-till for at least 5 years. Soil types included two sandy loams, one loam, and the rest silt loams and silty clay loams. Shallow-dwelling earthworms were counted by excavating and hand-sorting soil. The presence or absence of significant nightcrawler populations was determined by observing whether nightcrawler middens were present in the field.

**Results of the survey confirmed that no-till management generally leads to increases in earthworm populations**. Eight of the 14 sites had higher populations in no-till than in tilled fields, with increases ranging from 25% higher to 10 times higher. Four sites had roughly equal populations under both systems, and two sites had slightly lower populations with no-till. Populations ranged from a low of 2 to a high of 340 earthworms per square meter over all the sites and tillage systems surveyed. In addition, nine no-till and only three tilled sites had significant nightcrawler activity, again confirming the strong influence of surface residues on nightcrawlers. We don't know whether or not the other no-till sites will develop nightcrawler populations after more time in the system.

***Managed and/or ChemicallyTreated Fields***

As discussed earlier, there are many conventional fields where nightcrawlers are completely absent, presumably due to lack of surface food supply. When these fields are switched to a no-till system, the habitat is better for the nightcrawlers, but the only way a population can get started is by overland movement from nearby places that have nightcrawlers, such as fencerows, roadsides, grass waterways, etc. This is a slow process and may take many years before a field is populated. In addition, not all roadsides and fencerows have nightcrawlers either, so there may not be a "source" of nightcrawlers adjacent to every field. Finally, we don't know whether or not nightcrawlers will survive in all soil types, so some fields may be unsuitable even when *managed* for the worms. Much more study and observation of nightcrawlers in agricultural fields is needed in order to answer these questions.

*The impact of agricultural chemicals on earthworm populations varies with the chemical.* Inorganic nitrogen fertilizers promote greater plant production than in unfertilized fields and therefore higher earthworm populations. Although anhydrous ammonia will kill a few worms in the narrow band where injected, field effects are probably minimal due to the small area affected. There is little information on other nitrogen sources commonly used in the Midwest, but effects are probably small when used at typical field rates. *Most herbicides used in crop production in the Midwest are harmless or only slightly toxic to worms and should not be a great concern.* As discussed earlier, some corn rootworm insecticides are toxic to worms, but their effects can be reduced by keeping the application band as narrow as possible. In general, the organophosphate and pyrethroid insecticides are harmless to moderately toxic, while the carbamate insecticides and fungicides are highly toxic. Nematicides in general are also highly toxic.

## How to Encourage Earthworms

Earthworm populations can be increased by applying the concepts discussed earlier about food supply and surface mulch protection (Table 3). Leaving a surface mulch, by no-till or other conservation tillage systems with plenty of residue cover, will generally increase populations. Growing winter cover crops may augment the mulch protection as well as provide additional food for the worms. Adding or growing organic matter is a great way to build earthworm populations. Animal manures and sewage sludges, and rotations with hay or set-aside fields, are also possible ways to provide more food for the earthworms and help increase populations. Soil pH should be maintained between 6.0 and 7.0

**Table 3. Methods to increase earthworm populations.**

| | |
|---|---|
| Leave surface mulch: | |
| | no-till |
| | ridge-till |
| | cover crops |
| Add or grow organic matter: | |
| | manure |
| | hay |
| | set-aside |
| | cover crops |

for optimum conditions, although lower pH's are tolerated by most species. Although management can increase earthworm populations on many soils, some soils will not support high earthworm populations, regardless of management, due to inherent soil texture and drainage properties. Very coarse sands and perhaps high water table heavy clays are two examples.

The question often arises, "Is it worthwhile to "seed" earthworms in fields with low populations?" The first principle to remember is that the shallow-dwelling species are already established, and their current population is what can be supported by the current management system. If the management system is changed to something more suitable for the worms, their populations will increase quickly (1 or 2 years) to the level that can be supported by the new practices. Thus, there is little evidence to suggest that seeding these worms is worthwhile.

Nightcrawlers, however, may be a slightly different story. Since many conventional fields have no nightcrawlers present, a change in management from conventional to no-till does not guarantee that nightcrawlers will become established (see earlier discussion). Under these circumstances, there may be some benefit from establishing a few sources of nightcrawlers in the field, and several farmers have claimed success in establishing nightcrawlers in this way. Whether nightcrawlers would have established themselves in these fields without the farmer's assistance is not known. If you want to try this practice, collecting local nightcrawlers from country roads or pastures on rainy spring nights or mornings is a good way to start. Purchasing nightcrawlers is expensive, and they may not be adapted to local soils and climates. A small-scale, low-cost trial is highly advisable, since we don't know whether or not nightcrawlers will survive on all soils. Protect the worms from the sun, and place 4 or 5 together under some mulch or residue in a spot every 30 or 40 feet in the field, preferably on a cloudy, wet, cool day. Record the location of the seeded spots, and then observe those spots for evidence of midden activity over the year to determine whether the nightcrawlers survived and if the patches are growing.

## Remaining Questions and Further Information

Many questions about earthworms and agricultural fields remain to be explored. How much do earthworms contribute to nutrient cycling and availability to an annual crop? How much improvement in soil physical properties can be expected from both shallow-dwelling species and nightcrawlers? Why are nightcrawlers present in some no-till fields and not others? What practical management strategies might be used to help establish nightcrawlers in areas that have none? These and other questions have potential importance for increasing the sustainability of agricultural systems.

## References

More detailed information about earthworms can be found in the books listed below.


Edwards, C. A., and J. R. Lofty. 1977. *Biology of Earthworms*, 2nd. ed. Chapman and Hall, London. 333 pp. (3rd edition in preparation).

Lee, K. E. 1985. *Earthworms: Their Ecology and Relationships with Soils and Land Use.* CSIRO, Sydney Australia. 411 pp.

Reynolds, J.W. 1977. *The Earthworms of Ontario.* Royal Ontario Museum, Toronto. 141 pp.


This last book includes primarily morphology and taxonomy, including diagrams and a taxonomic key, for serious students of earthworm speciation. Most of the common species in agricultural fields of the central Cornbelt are included.