# Impact of Organic Crop and Livestock Systems on Earthworm Population Dynamics

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## Abstract

*Earthworm population dynamics and diversity were evaluated in long-term farming systems experiments at the West Virginia University Organic Research Farm from 2000-2007. Farming systems included vegetable and field crop rotations, with versus without annual compost amendments. Field crop rotations with livestock included three years of clover-grassland. Earthworms were monitored by hand-sorting soil samples. Aporrectodea caliginosa and Lumbricus rubellus were the most common species observed. Cultivation adversely affected earthworm populations in all systems, while compost amendments either had no effect or increased earthworm populations. The population structure shifted toward younger age classes and lower biomass. Inclusion of clover-grassland in the rotation for pasture and hay production for sheep had no significant effects on populations in the field crop systems.*

## Introduction

Earthworms are generally considered to be important indicators of soil quality and provide well-known benefits through cycling of organic matter and improving soil porosity and aeration (Edwards, 1998). Earthworms are also known to be sensitive to synthetic pesticides, thus transition from conventional to organic practices is believed to enhance earthworm activity in soil.

The West Virginia University Organic Research Farm project was initiated in 1999 as a long-term evaluation of organic farming systems. Prior to this time, the Farm had been in conventional horticultural production, primarily tree fruits and vegetables. Soils are silt-loam and slopes range from 0-24 %, typical of Appalachian hill top farms. The initial three years of the project involved a transition from conventional to organic management, with organic certification granted in 2003. Since that time, farming practices in this trial adhere to USDA organic certification requirements. The project was designed to evaluate the impact of several organic farming systems on crop and livestock productivity, soil quality, populations of pests and beneficial organisms, and overall farm profitability. This paper reports on the long-term changes in earthworm populations, biomass, and age structure in these farming systems.

## Materials and methods

Two replicated farming systems experiments, market garden and field crop/livestock, were conducted. Each compared two treatments for managing soil quality during the transition from conventional to organic practices: a low input transition using cover crops only, and a high input treatment using off-farm compost amendments with cover crops. The field crop system also included two additional treatments, with- and without-livestock, arranged in a factorial design with the two transition (high vs low input) treatments. Prior to initiation of the experiment, all plots had been managed as permanent grassland or as a conventional apple orchard with grass sod as ground cover for at least ten years.

**Low Input Treatment.** Plots were cover cropped intensively beginning in Fall 1999 and throughout the 2000 growing season. Rye, sown in fall, 1999, was followed by clover in spring, 2000 and by rye and vetches in the fall of 2000. All cover crops were plowed in as green manure. This treatment was used to build soil quality and yielded no saleable product in 2000. Market garden plots were cropped, starting in 2001, with a 4-year rotation sequence of legumes (beans and peas), leafy vegetables (spinach and lettuce), solanaceous crops (tomato and pepper), and cucurbits (zucchini and pumpkin). Field crop plots in the without-livestock systems were cropped to wheat, potato, forage soybean, or Brussels sprouts. A rye-vetch winter cover was planted each year on all plots, except those with an established overwintering crop. Beginning in 2003, forage rape was substituted for brussels sprouts, and a summer cover crop of cowpea was inserted in the rotation between wheat and forage rape crops. Field crop plots in the with-livestock systems followed a seven-year rotation, with cultivated crops for four years, followed by three years with orchard grass-red clover.

**High Input Treatment.** Following the rye cover crop planted in Fall 1999, plots were amended with a dairy manure compost at 10 T/acre in the spring of 2000. Crops in the field crop and market garden plots were the same rotation as for the Low Input system. Thus, the High Input treatment used off-farm compost to improve soil quality and produced saleable crops in the first year of transition. Compost was applied at 10 T.acre each year to High Input plots in the Market Garden and through 2003 in the Field Crop plots. Beginning in 2004, compost was applied at 20 T/acre in the potato and wheat crops, with no compost applied in the high input soybean, cowpea, or forage rape crops.

The market garden had four replications of the two treatments and four crop families in all combinations (32 plots total). The field crop system had three replications of the low and high input systems with and without livestock, in all combinations (66 plots total). Sheep grazed the plots, with stocking density assigned at a level to minimize purchases of off-farm feed. Soil samples were collected to monitor soil earthworm fauna. Three soil cores (10-cm-diam by 15-cm-deep) were collected from each plot and eahrthworms were collected in the field by hand sorting. Worms were placed in vials on ice and returned to the lab where they were sorted by species and age class, and then oven-dried at 45 C to determine biomass. Worm fragments were counted as one-half of a worm, and fragments without an identifiable head were designated as unknown species. Worm populations were monitored in the Market Garden systems in spring of each year from 2000 through 2007 (except 2005), generally before the first tillage operations. Field crop systems and summer and fall populations in the Market Garden were also monitored through 2004.

## Results

The dominant species in both field crop and market garden plots was *Aporrectodea caliginosa*, with *Lumbricus rubellus* also occurring frequently. *L. terrestris* was rare, and largely disappeared from the plots after a few years of cultivation. Although population densities increased during 2006 and 2007, the proportion of adults declined from 57 % of identified individuals in 2001, to only 26 % by 2007. Population density was significantly greater in market garden plots with high compost inputs on 6 of the 15 sample dates (Figures 1A and 1B). Similar trends in field crop plots were observed, but differences were statistically significant only for biomass at one date (Fig. 1 C and 1 D).

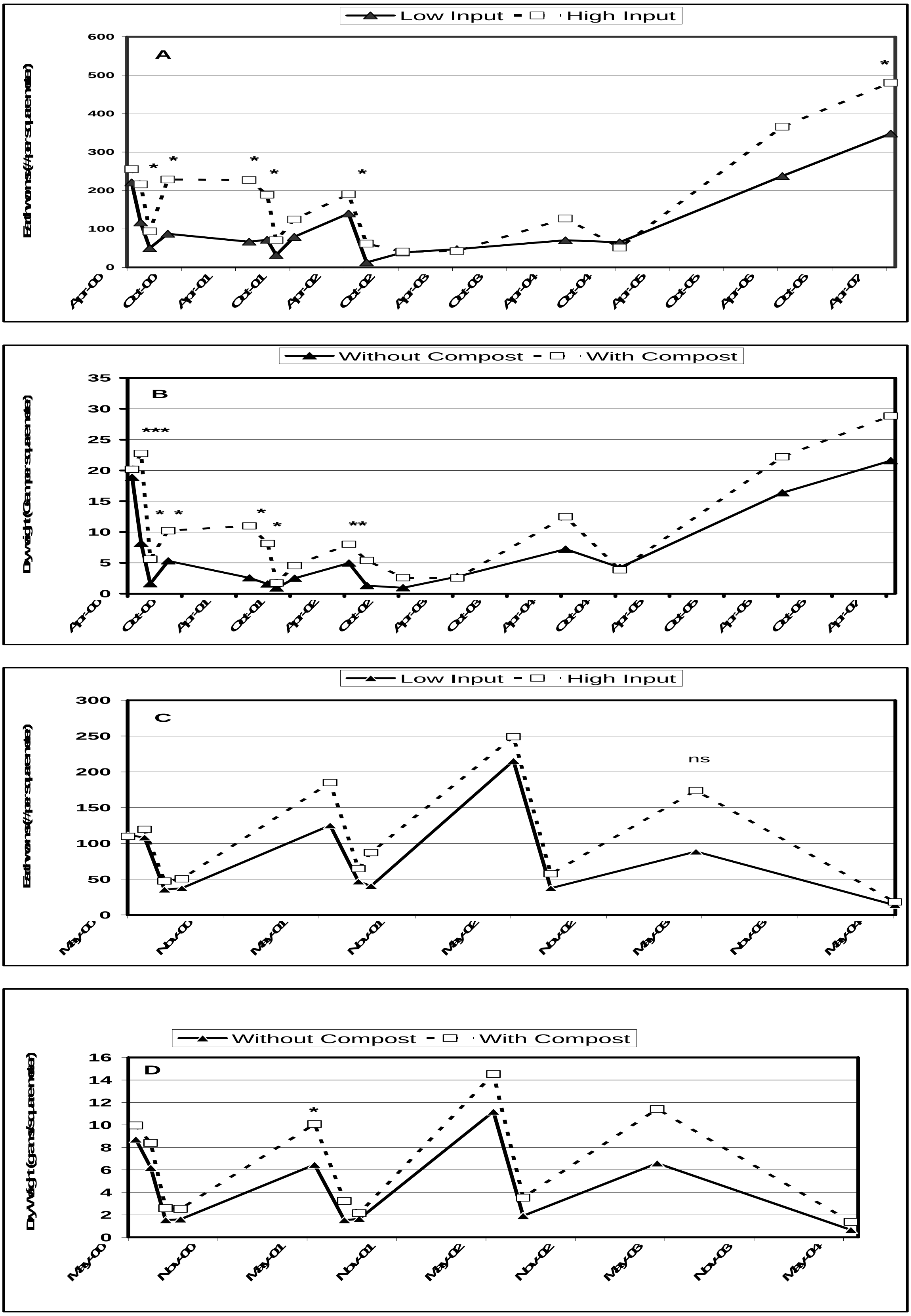


**Figure 1: Earthworm population density (A) and biomass (B) in vegetable market garden systems and in Field Crop Systems (C and D) amended with 10 Tons Dairy manure compost per acre (High Input) or unamended (Low Input).**

## Discussion

Earthworm populations respond to agroecosystem management practices. Adverse effects of tillage on earthworm populations are well known (Edwards and Lofty, 1982; Rovira, et al. 1987). Anecic species such as *L. terrestris* are particularly sensitive, and largely disappeared from plots in this study after continuous cultivation began. The population age structure of the less sensitive species in our plots was also affected, as the majority of individuals collected in 2000 and 2001 were adults, but the populations became increasingly dominated by juveniles, with adults constituting only 26 % of the population by 2007. The declines observed in mid-summer may have been a direct result of spring tillage operations, or simply a sampling artefact due to earthworms moving during hot dry weather to soil layers deeper than the depth of our samples.

Other studies show that addition of organic substrates that serve as food sources can stimulate earthworm populations (Curry, 1976). In our study, population density and biomass were consistently greater in both field crop and market garden plots receiving dairy manure compost than in plots without compost, although differences were not always statistically significant. The host crop planted rarely had a significant or consistent effect, although there was a trend toward higher populations in market garden plots with tomato and pepper, and in field crop plots planted to orchard grass-red clover grasslands. The higher earthworm populations in tomato and pepper plots may have been due to the use of hay mulch for weed suppression, rather than a specific effect of these crops.

Few studies have examined the effects of livestock on earthworms. Hutchinson and King (1980) indicated that earthworm populations were greatest when the stocking rate of sheep was kept at levels associated with maximum productivity, however few other studies have found comparable effects. While the absence of cultivation may tend to promote earthworm populations, trampling has been shown to adversely affect earthworms living near the soil surface. In our plots, sheep grazed only for short periods, and no effects were discernible.

## Acknowledgments

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