Earthworm density and activity across three agroecological zones

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Greenhouse experiments have shown that earthworms have the potential to increase crop yields by improving nutrient cycling, water infiltration, and soil structure. Many of these experiments, however, use densities of earthworms that are much greater than those found in agricultural fields. In addition, earthworm experiments are often carried out under ideal soil temperature and moisture levels, promoting constant earthworm activity.

In reality, soils sometimes experience rapid drying and warming during the growing season, which may result in earthworms entering a hibernation-like state known as aestivation. Aestivation allows earthworms to survive arid conditions by reducing surface area and stopping metabolic activity. Aestivating earthworms cease feeding, create a small chamber (Figure 1), and remain coiled and inactive until soil conditions are favorable.

IMPACT

The ability to curl up in a ball and aestivate (enter a hibernation-type state) allows earthworms to survive temporary periods of warm, dry conditions, but may limit their impact on soil properties and plant growth. Earthworm density and biomass seem to be more related to soil moisture content than to temperature.

The onset and length of earthworm inactivity in the inland Pacific Northwest, which experiences significant dry-down and warming during the late spring and summer months, are unknown, and aestivation may moderate expected positive influences of earthworm activity on soil processes and plant growth. This study compares earthworm densities and aestivation between the spring and summer in three agroclimatic zones of the wheat production region to provide an initial characterization of aestivation cycles in dryland wheat production systems within the inland Pacific Northwest.

Figure 1. *An earthworm found aestivating in the summer of 2013. The coiled worm is approximately 1.5 cm in diameter. Photo by Chelsea Walsh.*

Figure 2. *A REACCH summer intern and staff member sample a field for earthworms. Photo by Chelsea Walsh.*

In the spring of 2012 and 2013, 40 sites across the region were sampled for earthworms (Figure 2). In June and July of 2013, the 20 sites where earthworms had been detected in the spring were resampled. Earthworm density (worms per square meter), volumetric soil moisture content, soil temperature, and the presence of aestivating earthworms were recorded. Earthworms were collected from two 25 x 25 x 50 cm pits in each field, using hand sorting and sifting. Each field sampled was placed into one of three agroclimatic zones (annual, transition, or crop-fallow) based on the proportion of crop to fallow and the presence of irrigation around each pixel of the CropLand data layer.

As anticipated, average soil moisture in the top 30 cm of soil decreased in all zones between the two sampling periods, while average soil temperature increased across all zones. Across zones, soil moisture decreased an average of 10.4%, and soil temperature increased an average of 3.4°C at sites where earthworms had been found. Earthworm density ranged from 8 to 190 individuals m^{-2} (average 66.3) in the spring and from 0 to 45.8 individuals m^{-2} (average 9.9) in the summer. The decrease in earthworms is most likely a combination of mortality and movement by earthworms deeper into the soil, where soil temperatures are lower.

In the spring of 2013, aestivating earthworms were found at only 3 of the 20 sites. These sites had an average soil moisture of 21% (compared to an average of 27% for all sites in the spring).

Figure 3. *The invasive earthworm* Aporrectodea trapezoides *is the most common species in agricultural fields of this region. Photo by Chelsea Walsh.*

Finding aestivating earthworms in spring was unexpected. In addition, all aestivating earthworms were in the transition zone, which generally receives greater precipitation than does the fallow zone. These results indicate that field-level variability may significantly influence activity periods, even within a climatic zone. In addition to climate, other factors such as soil organic matter, bulk density and management practices likely play a role in determining earthworm density and activity.

In the summer, earthworms were either aestivating or not present at 8 of the 20 sites, with both aestivating and active earthworms present in all three zones. Summer data suggest that earthworms may be able to maintain activity at soil moisture levels of as low as 14 to 19%.

Earthworm density and biomass seem to be more related to soil moisture content than to temperature (Figure 4). Greater sensitivity to soil moisture is consistent with the observation that earthworms tolerate higher temperatures when soil moisture levels are also high. It is important to recognize, however, that soil moisture and temperature tend to change in similar patterns, and that both properties impact earthworm survival.

While the aestivation data presented here are preliminary in nature, they do suggest that patterns of aestivation may be difficult to interpret at the regional scale. The ecological significance of aestivation on soil properties and plant growth in interior Pacific Northwest agroecosystems is unknown and will be the topic of future greenhouse and field studies.

Figure 4. *Relationship between earthworm density and soil moisture at the time of sampling across zones. Earthworm densities were generally higher at higher soil moisture levels, with much greater densities occurring in spring.*