Earthworm population response to tillage and residue management in central Iran

Mojtaba Yahyaabadi[A] and Ardeshir Asadi[B]

[A]Department of Soil and Water Research, Isfahan Agriculture Research Center, Isfahan, Iran, Email mo_yahya@yahoo.com
[B]Department of Agriculture Engineering, Isfahan Agriculture Research Center, Isfahan, Iran, Email, asadi2002@yahoo.com

Abstract
Tillage can affect earthworms directly by the mechanical action of the tillage operations as well as indirectly as a result of the consequent changes in soil environment. The objective of this study was to investigate the effect of tillage practices on earthworm populations used as an indicator of soil biological status using different tillage practice. Earthworm populations, cocoons and live earthworm masses were significantly different for the treatments within three years reflecting practices and residue management. Results showed that a majority of the earthworms were found 5-15 cm deep in the plots and the large-bodied anecic species were more abundant in the minimal-tilled soils, whereas the endogeic species, which were smaller in size, were more abundant in the conventionally-tilled soils.

Key Words
Anecic, earthworms, tillage, residue.

Introduction
For millions of years earthworms were Nature's plough and were responsible for maintaining the soil in suitable physical condition. Until recently, modern agriculture has been often accompanied by intensive tillage with heavy machinery. Many farmers, organic gardeners and researchers have recognized earthworms as important organisms contributing to healthy soils. Tillage can change the abundance as well as the composition of earthworm populations. The actual impact is dependent on soil factors, climatic condition, the tillage operation and residue management; but this information is still not well documented. Low (1972) reported that earthworm populations in fields in England, which had been tilled for 3 and 25 years, were respectively, 50 and 15% of those found in old grassland. Increases in earthworm populations after tillage were usually observed after ploughing of pasture and the associated burying of large quantities of plant material. Earthworms, whose primary source of food is partially decomposed plant tissue, are expected to flourish in the short-term (Lee 1985). Edwards and Lofty (1969) reported that after an initial increase in the first two seasons, a progressive decline in earthworm populations under repeated tillage occurred over the following seasons. According to Lee (1985), the gradual decline in earthworm abundance with successive tillage after the initial increase was due to subsequent adverse changes in soil environmental conditions as a result of loss in soil aggregate structure and reduction of soil organic matter content. Tillage is often defined as the mechanical manipulation of soil physical conditions. Therefore, tillage can affect earthworms directly by the mechanical action of the tillage operations as well as indirectly as a result of the consequent changes in soil environment. The objective of this study was to investigate the effect of tillage practices on earthworm populations used as indicator of soil biological status using different tillage practices and residue management.

Materials and methods
Conservation and conventional tillage systems in the presence of barley stubble on forage corn biomass were established to assess the impact of management practices on earthworm populations. The soil was a silty clay loam at Kabootar Abad research station, 40 km southeast of Isfahan, central Iran. The six treatments were: 1- burning barley stubble + moldboard plowing to a depth of 25cm + disking (MPB) 2- shredding the stubble + moldboard plowing to a depth of 25cm + disking (MPC) 3- incorporation of the stubble by plowing to a depth of 25cm + disking (MPS) 4- chisel plowing to a depth of 10cm + mixing the stubble with the soil surface with a rotary tiller (CPC) 5- shredding barley stubble + direct drilling with Amazon (NT250) no-till drill (NCM) 6- shredding the stubble + irrigation + hand planting (NCH). Each treatment was established with three replicates in a randomized block design. Earthworm populations were measured annually in situ from four random positions in each plot by removing replicate samples of soil (25cm x 25cm x 25cm) from each treatment plot. Earthworms contained in the soil samples were carefully removed by hand-sorting

(Edwards and Bohlen 1996) and were subsequently identified (using the key of Edwards and Lofty 1977), age-classified and weighed to ascertain the earthworm population size, composition and biomass for each treatment**.**

Results and Discussion

Earthworm populations, cocoons and live earthworm masses were significantly different in the treatments within three years (Table 1). The amount of crop residues on the soil surface, and low soil disturbance under the (NCH) and (NCM) treatments, were most likely factors, which encouraged the proliferation of the earthworm population. These results are similar to those reported by other researchers (Francis and Knight 1993; Karlen *et al.* 1994). No-tilled plots had a greater population density and biomass of earthworms and cocoons than the tilled plots. The size (mean weight) of adult earthworms and the numbers of cocoons per adults were also greater in the no-tilled plots. However, no differences in earthworm populations were detected between minimum tillage (CPC) and stubble incorporation (MPS). Burning stubble (MPB) resulted in significantly smaller adult earthworms, a lower density of cocoons and a lower mean number cocoons per adult than in unburnt plots, but the differences in numerical abundance and in biomass were not statistically significant. Results also showed that a majority of the earthworms were found 5-15 cm deep in the plots and the large-bodied anecic species were more abundant in the minimal-tilled soil (CPC) whereas the endogeic species, which were smaller in size, were more abundant in the conventionally-tilled soil (MPC and MPS).

†Table 1. Effect of tillage practices on earthworm population, cocoon and earthworm live mass.

‡Treatments	**Earthworm (no.m^{-2})**	**Cocoon (no.m^{-2})**	**Earthworm live mass (g m^{-2})**
NCH	219a	120a	82a
NCM	228a	116a	78a
CPC	130b	115a	37b
MPS	118b	77b	37b
MPC	65bc	68b	16c
MPB	33c	29c	13c

Values followed by the same letter in columns show no significant differences ($p<0.05$).
†Values are for the plots after 3 years of the treatments and for the top 25 cm of soil.
‡See text for definitions.

Conclusions

Our findings show that rotation with reduced tillage increased earthworm numbers. These results also confirm that continuous tillage plays a major role in declining earthworm populations. Previous studies found that the greater the intensity and frequency of tillage, the lower the population density of earthworms (Gerard and Hay 1979; Mackey and Kladivko 1985). Different species of earthworm respond differently to tillage. While the abundance of the deep burrowing species (anecic) tends to decline under tillage, particularly under deep ploughing, endogeic species can actually increase in number especially when there is increased food supply. Under conservation tillage systems, earthworms can potentially play a more important role than under conventional tillage in the functioning of the farming systems because of their abilities to modify the soil physical environment and nutrient cycling. More research is needed to fully understand the ecology of different earthworm species, their interactions and their potential roles in promoting more sustainable farming systems.

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