RESEARCH PROJECT TITLE: Examination of Tillage Factors, Crop Type, Soils and Non-crop Habitat upon Soil Fauna and Ground Dwelling Predators in a Small Inland PNW Watershed.

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FINAL REPORT

PROJECT OBJECTIVES:
1. Determine the ground dwelling predator fauna of spring wheat and pea grown under conventional-till (CT) and reduced-till, and the overlap of such fauna with that found on natural habitats.
2. Ascertain the ground dwelling predator fauna of specific natural habitats within the Palouse.
3. Determine the relationship between soil macrofauna, crop rotation, and soil fertility.
4. Examine controls over C and N distribution across a typical, direct-seeded Palouse hillslope.

KEY WORDS: spring wheat, pea, biodiversity, earthworms, nitrogen, carbon

STATEMENT OF PROBLEM: Conventional-tillage (CT) can be beneficial for integrated pest management efforts by destroying pest species. Research indicates, however, that conservation-tillage (ConsT) systems more often than not reduce pest incidence in comparison to CT. This is due, in part, to the conservation of natural enemies within ConsT fields. Soil- and litter-dwelling (‘epigeal’) natural enemies (e.g. ground beetles and spiders) are especially benefited by ConsT (Stinner and House 1990). Natural enemy enhancement is well documented in annual cropland of the Midwestern and Southeastern United States (Stinner and House 1990). However, in some agricultural regions, e.g. the Northern Great Plains, the benefits of ConsT for natural enemy enhancement are less clear (Carcamo et al. 1995), while in the Palouse region of NE Idaho, the influence of tillage on epigeal predatory fauna has been largely unexplored.

Along with an expected increase in epigeal predatory fauna, earthworm populations have been found to increase in ConsT systems. Increased earthworm densities may enhance yields through improved soil physical properties, aeration, infiltration and nutrient cycling. The presence of residue layers in ConsT may result in greater levels of nitrogen immobilization and soil organic matter. Little is known about how earthworms influence nitrogen availability and carbon sequestration rates in direct seed (DS) fields in the Palouse region.

ZONE OF INTEREST: High rainfall, Palouse

ABSTRACT OF RESEARCH FINDINGS: Pitfall and bulk soil samples indicate that both tillage and crop have a significant influence on invertebrates. Five species of ground beetles were found to account for the majority of beetles captured during the study. These numerically-dominant species appear to respond in an idiosyncratic manner to both crops and tillage. Some species were more “abundant” (as reflected by higher trap catches) in pea than in wheat, others were more abundant in ConsT than in CT, and crop x tillage interaction effects were common. Consistent response patterns to tillage were also observed during the study, and for some species...
the patterns were the same as those observed at the Kambitsch farm. These results suggest that reduced tillage systems on the Palouse may conserve some ground beetles species while suppressing others. Spiders were also found to vary in response to tillage, although trap catch was generally higher for this group in ConsT than in CT. Additionally, we found that the pestiferous pea-leaf weevil (*Sitona lineatus*) was significantly less abundant in ConsT than in CT pea during 2002, while no mean differences were observed in 2003. Earthworm and cocoon densities were generally higher under ConsT as compared to CT. Levels of plant available N appear to be influenced more by crop than by tillage due to differences in fertilization practices between the crops. Total nitrogen and carbon content were higher in the first 10 cm of soil under ConsT as compared to CT.

**METHODS:** This project builds upon STEEP funded research at the Kambitsch Research Farm. Since 2000, tillage effects on invertebrate fauna in a 3-yr crop rotation (winter wheat, spring wheat and spring pea) at Kambitsch have been evaluated. Controlled replication is a strength of the Kambitsch experiments, but it is necessary to examine the effects of tillage on actual farms. On-farm research eliminates boundary and edge effects inherent in small plots, a particular concern for arthropod species that readily disperse across plot boundaries. On-farm research provides an opportunity to quantify the average response of invertebrate fauna to tillage under heterogeneous conditions. Thus, this project extended the research being conducted at Kambitsch to large-scale fields on working farms.

To standardize the sampling methods employed during this broader-scale study, we sampled only CT (conventional tillage) and ConsT spring pea and spring wheat crops. These fields had similar cropping histories to those at Kambitsch, although the topographical features and soil types were more varied within these fields than within the plots at Kambitsch. Only fields located in the high-rainfall zone of Nez Perce and Latah counties were included in the study. A total of 24 fields were sampled.

To capture the ground-dwelling arthropods, 5 pitfall traps were placed equidistantly along 2 transects within each field. In both years the sample was stratified by placing transects on both warm (south and west) and cool (north and east) aspects. The pitfall traps consisted of 9 oz. plastic drink cups set in plastic liners flush with the soil surface. Each trap was filled weekly with 1 to 2 oz. of low-toxicity antifreeze. Arthropods that fell into the traps were preserved by the antifreeze and collected on a weekly basis. Trap contents were processed by transferring all specimens into 70% methanol. However, due to insufficient resources, only the trap contents from every other trap collected during 2003 were processed, whereas all trap contents from the 2002 sampling were processed. Adult beetles were identified to the lowest taxonomic level feasible and counted, whereas spiders were treated as a single taxon and counted. Each trap location was recorded with an ETREX GPS unit, and these location data were subsequently imported into a GIS.

Earthworms and soil were sampled from four small pits (approximately 20 by 30 cm) that were dug along each transect. To minimize the influence of factors outside the scope of this study soil and earthworms were sampled only on cool aspects and at the same landscape position in each field during 2003, in contrast to beetles which were sampled along both aspects in both years.
Earthworms were returned to the laboratory, weighed and preserved in formalin. Soil samples were air dried, gently ground and sieved to obtain the less-than-2-mm size fraction. Inorganic N was determined by extraction with 2 M KCl. Total C and N were determined by dry combustion in a CNS analyzer. Soil pH was determined on a 1:1 (soil:water) mixture.

RESULTS AND INTERPRETATIONS:

**Soil Properties:** General soil properties including total C and N, pH, and inorganic N were analyzed from soil samples taken from each pit at the same time as earthworm collection. Soil pH ranged from approximately 4.7 to 6.1 across tillage, crop, and year at the 0-10 cm depth and tended to be lower in fields sampled in 2003 as compared to 2002 (Fig. 1). Increases in acidity have been noted in ConsT soils on the Palouse, however, no significant differences were detected between tillage types in this study. The lack of differences may be due to inherent variability in the selected fields or due to differences in the length of time that fields have been under ConsT management. Mean total C, across years, ranged from 1.8 to 2.3% in the 0-to 10-cm depth of ConsT soils compared to a range of 1.7 to 1.9% at the same depth under CT (Fig. 2). The data suggest that more C is held in near surface soil horizons under ConsT within the Palouse. Additionally, there was no evidence of C depletion with depth under ConsT. Total N followed the same pattern as C (Fig. 3), since organic matter is an important source of N. There were no obvious differences in total inorganic N (ammonium and nitrate) in ConsT and CT fields in 2003 (Fig. 4). Differences in plant available N near the soil surface in 2003 is likely a result of differential fertilization practices between wheat and peas.

**Ground Beetles:** Five numerically-dominant species of ground beetles were captured during the study: *Poecilus scitulus*, *Pterostichus melanarius*, *Poecilus lucublandus*, *Calosoma cancellatum* and *Microlestes linearus*. These species were the same dominants as those captured in the Kambitsch experiments. In both years the dominant species responded in an idiosyncratic manner to crop and tillage, often times with the same species responding differently to tillage in pea than in wheat (Fig. 5). This finding is not inconsistent with that of other regions, especially in cereal agroecosystems of the northern US and the great plains of Canada (Carcamo et al. 1995). The divergent response of dominant species to agronomic practices potentially confounds efforts to understand the overall response of carabid beetles to tillage. Despite this idiosyncratic response, some consistent patterns were observed during the study. For instance, in 2002, trap catch of four of the five dominant species, especially *P. scitulus*, was significantly higher in CT than in ConsT pea. This same response pattern was observed in 2003 for two of the five dominant species. In 2002, trap catch of *Pt. melanarius* and *P. lucublandus* was significantly higher in ConsT than in CT wheat, with a trend in the data suggesting a similar response pattern in 2003 for *P. lucublandus* (Fig. 5). Similar response patterns by these species to tillage were also observed at Kambitsch. We found that spiders responded idiosyncratically to tillage, although trap catch for this group of generalist predators was greater more often in ConsT than in CT systems (Fig. 6). In contrast, we found that trap catch of the pestiferous pea leaf weevil was significantly lower in ConsT than in CT pea during 2002 (Fig. 7), while no mean differences were detected in 2003.

Many correlations were detected between soil nitrates, N, C or pH and trap catch of ground beetles during the study, but only a few were consistent across years or tillage systems. For
instance, we detected significant correlations between soil nitrate concentrations at various depths and pitfall catch of dominant beetles (correlations too numerous to list). We detected a significant correlation between pH in the upper soil profile and *P. scitulus* in CT during 2002 ($R = 0.64, P = 0.02$) and 2003 ($R = 0.79, P = 0.06$). And lastly, we detected significant correlations between C and N concentrations at various depths in CT and ConsT and trap catch of *Pt. melanarius* during 2002, but not during 2003.

Some significant correlations between trap catch of beetles and soil A horizon thickness were detected. Trap catch of *P. scitulus* was positively correlated with depth of A horizon in pea fields during 2002 ($R = 0.52, P = 0.09$), 2003 ($R = 0.79, P < 0.01$) and across both years ($R = 0.52, P < 0.01$). In contrast, trap catch of *Pt. melanarius* was negatively correlated with depth of A horizon in pea during 2003 ($R = -0.60, P = 0.04$). Correlations by tillage system were less evident, although marginally significant correlations between trap catch of *P. scitulus* and depth of A horizon were detected in CT systems during 2003 ($R = 0.53, P = 0.08$) and across 2002 and 2003 ($R = 0.38, P = 0.07$). These results suggest that crop, tillage, soil properties and morphology influence trap catch and distribution of the most abundant ground-dwelling predatory fauna on the Palouse.

**Earthworms**: Reduced tillage systems have been found to support higher numbers of earthworms than CT in numerous studies across widespread areas. Higher earthworm populations under ConsT as opposed to CT are believed to result from less physical injury, decreased soil disturbance, and lower susceptibility to predation by birds combined with a more continuous food supply and favorable soil environmental conditions (Edwards and Lofty, 1982; Lee, 1985; Kladivko, 2001). Although earthworm numbers tended to be slightly higher in ConsT as compared to CT fields, no significant differences were detected (Fig. 8 and 9). Consistent with data collected at Kambitsch, however, earthworm cocoon densities were higher in ConsT fields as compared to CT fields. Increased soil moisture and consistent food supply under ConsT appear to lead to greater cocoon production in the spring. Given the difference in reproduction rate, more significant differences in earthworm density were expected. The lack of more obvious differences in earthworm density in this study suggests that other factors such as low soil moisture and high temperatures in summer control earthworm density. Despite the ability of the insulating residue layer under ConsT to reduce evaporative losses and cool the soil in summer, soil moisture and temperature may reach levels lethal to earthworms during the summer in these dryland, ConsT agricultural soils.

Correlation analysis was performed using 2003 data (cool aspects only) to relate earthworm and cocoon densities and net earthworm weight to soil properties. A positive relationship was found in ConsT between total soil C at 10-to 20 and 20-to 30-cm depths and earthworm numbers (Table 1). A similar relationship existed between total soil N and earthworm activity, since total N and C are highly related. Higher soil organic matter relates to an improved food source for earthworms. Additionally, earthworm activity tends to increase mixing of organic residues into soil surface horizons. Earthworm cocoon counts in ConsT were positively correlated with total C at 0-10 and 10-20cm depths (Table 1). Most cocoons were found within the upper soil horizons where earthworm activity is expected to be high in the spring when cocoon production is expected to be at a maximum. Correlation analysis of 2002 data (warm and cool aspects)
revealed no significant correlations to earthworm density with total C and N in ConsT. Cocoon density in ConsT was, however, significantly correlated with total C at 0-10, 10-20, and 20-30 cm and with total N at 0-10, 10-20, 20-30, and 30-40 cm depths. CT fields revealed only isolated correlations, presumably due to the confounding effects of soil disturbance from tillage. Across years few significant correlations were found between either inorganic N or pH and earthworm or cocoon densities.

Table 1. Correlation matrix (R values) of total soil carbon influences on earthworms and cocoon densities in 2003.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>CT Worm Density</th>
<th>NT Worm Density</th>
<th>CT Wet Worm Weight</th>
<th>NT Wet Worm Weight</th>
<th>CT Cocoon Density</th>
<th>NT Cocoon Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>0.10</td>
<td>0.78</td>
<td>0.27</td>
<td>0.80</td>
<td>-0.55</td>
<td>0.84*</td>
</tr>
<tr>
<td>10-20</td>
<td>-0.37</td>
<td>0.89*</td>
<td>0.17</td>
<td>0.85*</td>
<td>-0.72</td>
<td>0.86*</td>
</tr>
<tr>
<td>20-30</td>
<td>0.39</td>
<td>0.81*</td>
<td>-0.08</td>
<td>0.94*</td>
<td>0.33</td>
<td>0.57</td>
</tr>
<tr>
<td>30-40</td>
<td>0.61</td>
<td>-0.06</td>
<td>0.22</td>
<td>0.22</td>
<td>0.46</td>
<td>-0.18</td>
</tr>
<tr>
<td>40-50</td>
<td>0.76</td>
<td>-0.30</td>
<td>0.39</td>
<td>-0.02</td>
<td>0.50</td>
<td>-0.36</td>
</tr>
</tbody>
</table>

* indicates $P<0.05$
Fig. 1 Mean pH values for 2002 (A) and 2003 (B) with depth for ConsT and CT peas and wheat. Samples were taken from 10-cm increments to a depth of 50 cm. Points are shown at the midpoint between sampling intervals.
**Fig. 2** Mean total carbon (%) with depth for conventional-till (CT) and ConsT (NT) peas and wheat. Samples were taken from 10-cm increments to a depth of 50 cm. Points are shown at the midpoint between sampling intervals.

**Fig. 3** Mean total nitrogen (%) with depth for conventional-till (CT) and ConsT (NT) peas and wheat. Samples were taken from 10-cm increments to a depth of 50 cm. Points are shown at the midpoint between sampling intervals.
Fig. 4 Mean inorganic (plant available) nitrogen (sum of nitrate and ammonium) with depth for 2002 (A) and 2003 (B) for CT and ConsT peas and wheat. Samples were taken from 10-cm increments to a depth of 50 cm. Points are shown at the midpoint between sampling intervals.
Fig. 5. Response of numerically dominant ground beetles to tillage in large-scale commercial spring pea and wheat fields across Latah and Nez Perce counties, Idaho, 2002 - 2003. Here CT = conventional tillage and ConsT = conservation-tillage. * = significant differences at the $P \leq 0.05$ level, ‘MS’ = marginally significant differences at the $P < 0.1$ level.
**Fig. 6** Response of spiders to tillage in large-scale commercial spring pea and wheat fields across Latah and Nez Perce counties, Idaho, 2002 to 2003. Here CT = conventional tillage and ConsT = conservation-tillage. * = significant differences at the $P \leq 0.05$ level.

**S. lineatus**

*Fig. 7* Influence of tillage on the pea leaf weevil (*Sitona lineatus*) in large-scale commercial spring pea fields across Latah and Nez Perce counties, Idaho, 2002 - 2003. Here CT = conventional tillage and ConsT = conservation-tillage. * = significant differences at the $P \leq 0.05$ level.
Fig. 8. Number of worms and cocoons per m$^2$ in ConsT peas and wheat and CT peas and wheat in 2002.

Fig. 9. Number of worms and cocoons per m$^2$ in ConsT peas and wheat and CT peas and wheat in 2003.

REFERENCES:


INTERACTION WITH OTHER SCIENTISTS CONDUCTING RELATED ACTIVITY:
We interact with Stephen Guy, as this project is related to STEEP funded research under his direction that is being conducted at the UI Kambitsch Research Farm. We would like to thank the following individuals for allowing us to sample their fields, without which this study would not have been possible: Wayne Jensen, Nick Ogle, Mary-Jane Butters, Greg Moser, the Nelson family, John Hermann, Mike Becker, Mark Zenner and Russ Zenner.

PUBLICATIONS:


PRESENTATIONS:


