Pedobiologia 54 (2011) 79–86

Contents lists available at ScienceDirect

Pedobiologia - International Journal of Soil Biology

journal homepage: www.elsevier.de/pedobi

# Influence of agricultural soils on the growth and reproduction of the bio-indicator *Folsomia candida*

Karen Lindsey Nelson[a,*], Gilles Boiteau[b], Derek Henry Lynch[a], Rick Daniel Peters[c], Sherry Fillmore[d]

[a] Nova Scotia Agricultural College, P.O. Box 550, Truro, NS, Canada B2N 4L2
[b] Agriculture and Agri-Food Canada, Potato Research Center, 850 Lincoln Road, P.O. Box 20280, Fredericton, NB, Canada E3B 4Z7
[c] Agriculture and Agri-Food Canada, 440 University Avenue, Charlottetown, PE, Canada C1A 4N6
[d] Agriculture and Agri-Food Canada, 32 Main Street, Kentville, NS, Canada B4N 1J5

ARTICLE INFO

*Article history:*
Received 27 April 2010
Received in revised form
20 September 2010
Accepted 21 September 2010

*Keywords:*
Soil quality
Soil indicator
Potato rotation
Organic agriculture
Biological indicator

ABSTRACT

Soil organisms have been recommended as bio-indicators of soil quality due to their sensitivity to anthropogenic influences and their high degree of site-specificity. The objectives of this study were to determine if the relationship between the soil Collembola, *Folsomia candida*, and forest soil could be extended to other soils and, if not, to determine the relationship between its life parameters and soils from the different phases of an agricultural rotation sequence. A comparison of growth, reproduction and survival of 1 day old neonates and 10 day old juveniles subjected to a series of different soils (composted manure, pasture soil, forest soil, sand alone, and sand supplemented with yeast) established that the association between *F. candida* and forest soil quality cannot be automatically transferred to soils from other ecosystems. The test also showed that neonate (1 d) individuals were more sensitive to the different soil treatments than 10 d old juveniles and should be used in future tests. On this basis, neonate *F. candida* individuals were used to determine if the species could be employed to characterize the agricultural soils from the different phases of an organic or conventional rotation sequence. Results demonstrated that changes in body growth and reproduction constituted suitable criteria to characterize the soil quality of these different phases. The research required to develop these results as a standard bio-indicator test of agricultural soil quality is discussed.



## Introduction

There is increasing interest for authoritative information on the impact of agricultural land management on soil quality. This information is required to support the development of sustainable crop production practices and improve economic returns to growers. The production of crops like potatoes can substantially reduce soil quality and soil health under conventional management and even under environmentally sound organic crop management (Carter et al. 2003, 2004; Nelson et al. 2009). The reduction in soil quality is temporary but the period of time required for soil conservation and soil management efforts to restore soil properties to their original level in these fields has received little attention until now (Carter et al. 2009; Nelson et al. 2009). Assessment tools are required to determine the rotation interval needed to restore soil quality to its initial levels. The standard assessment methods for soil quality require a complex set of biological, physical and chemical data that is laborious and costly to acquire (Paoletti et al. 1991; Pankhurst et al. 1995; Nelson et al. 2009). The use of bio-indicators is a potentially less costly alternative approach (van Straalen 1998).

Collembola have been recommended as bio-indicators of management-induced changes in soil quality and soil health (Pankhurst et al. 1995; van Bruggen and Semenov 2000). These insects are closely associated with ecological keystone processes such as decomposition (Hopkin 1997; Fountain and Hopkin 2004; Tsiafouli et al. 2005) and nutrient cycling (Bitzer et al. 2005), and their feeding behaviour directly influences the microbial activity and biomass of the soil ecosystem. This close relationship between the bio-indicators and the systems can be exploited in two ways. The species composition and changes in the density of the insects (Collembola in this case) can be considered as early warning indicators of ecosystem change (van Straalen and Verhoef 1997; Carter and Noronha 2007). Alternatively, changes in key life history parameters of bio-indicator species after laboratory exposure to soil samples from different habitats can be used to determine the current relative status of these soils. This approach has the advantage of limiting the impact of top–down factors on the indicator thereby allowing a focus on bottom–up factors.

* Corresponding author. Tel.: +1 902 896 2469; fax: +1 902 896 7095.
*E-mail address:* klnelson@nsac.ca (K.L. Nelson).

0031-4056/$ – see front matter © 2010 Elsevier GmbH. All rights reserved.
doi:10.1016/j.pedobi.2010.09.003

**Table 1**
Chemical characteristics of soils used to study the growth, reproduction and survival response of 10 d and 1 d old *Folsomia candida*.

| Soil treatments | pH[a] | Carbon (%) | Nitrogen (%) | C/N |
|---|---|---|---|---|
| Series of selected soils | | | | |
| Composted manure | 7.22 ± 0.04a[c] | 23.00 ± 0.25b | 1.26 ± 0.02a | 18.3 ± 0.10b |
| Forest | 3.88 ± 0.01d | 33.2 ± 0.55a | 0.94 ± 0.03b | 35.4 ± 0.43a |
| Pasture | 5.50 ± 0.00c | 2.10 ± 0.03c | 0.18 ± 0.00c | 11.9 ± 0.18c |
| Sand alone | 5.95 ± 0.03b | 0.01 ± 0.00d | 0.05 ± 0.01d | 0.3 ± 0.06d |
| | ***[d] | *** | *** | *** |
| Series of agricultural soils | | | | |
| Po[b] | 5.72 ± 0.10a | 1.79 ± 0.03ab | 0.14 ± 0.012ab | 13.4 ± 1.22ab |
| Po + 3 | 5.92 ± 0.09a | 1.76 ± 0.05b | 0.13 ± 0.009b | 14.0 ± 0.36ab |
| Po + 4 | 5.68 ± 0.11a | 2.03 ± 0.06a | 0.14 ± 0.009a | 14.1 ± 0.65a |
| Pc | 4.27 ± 0.12b | 1.86 ± 0.01ab | 0.18 ± 0.001ab | 10.4 ± 0.32b |
| Pc + 1 | 4.37 ± 0.09b | 1.79 ± 0.01b | 0.17 ± 0.001b | 10.6 ± 0.06ab |
| Sand alone | 5.95 ± 0.03a | 0.02 ± 0.00c | 0.05 ± 0.01c | 0.35 ± 0.02c |
| | *** | *** | *** | *** |

[a] Means were backtransformed from square-root and log transformations and are based on three replicates.
[b] Indicates the treatment combinations assessed: Po, Po + 3, Po + 4, Pc, and Pc + 1 refer to the organic potato rotations: potato phase, three years after potato, four years after potato; and the conventional potato rotations: continuous conventional potato, two-year conventional rotation.
[c] Mean values followed by the same letter within a column are not statistically different (Tukey test; $P > 0.05$).
[d] *** means significant at $P < 0.001$ according to Fisher's LSD.

The species *Folsomia candida*, (Willem) (Collembola) is a good example of the latter approach, as this springtail has become the standard for many laboratory eco-toxicological tests (ISO 1999; Fountain and Hopkin 2005) and is considered a genomic model for soil quality testing (Timmermans et al. 2007). Its small size and short reproductive cycle make it ideal for conducting laboratory experiments. Also, its biology and ecology have been extensively reviewed in the literature (Christiansen 1964; Usher et al. 1971; Rusek 1998; Behan-Pelletier 2003; Fountain and Hopkin 2005) making it advantageous to try and broaden the use of this species rather than turning to lesser known species. *F. candida*, sometimes called the compost springtail, is found in a wide range of habitats extending from caves to forests and agricultural systems (Fountain and Hopkin 2005).

The potential of this bio-indicator of soil pollution as an indicator of soil quality has been explored by Kaneda and Kaneko (2002) in forest soils. These authors used the established effect of food availability in the soil on the fitness of *F. candida* (Fountain and Hopkin 2001; Crouau and Moia 2006) to demonstrate the existence of a relationship between the body growth of this springtail and the quality of forest soils. In their study, springtails were exposed to different proportions of a forest soil added to a standard artificial soil. Analysis showed that springtail body growth increased in proportion to total organic carbon, total nitrogen, microbial biomass C and respiration.

On the basis of these results, it was hypothesized that *F. candida* has potential as an indicator of changes in the quality of agricultural soils as they undergo different management practices. The first objective of this study was to determine if *F. candida* respond similarly to substrates from a wide range of origins as they do in forest soils. Body growth, reproduction and survival were measured for *F. candida* exposed to composted manure, pasture soil, forest soil, sand with yeast, and sand without yeast. The response was measured using 10 d old (recommended for ISO standard tests) and neonates (expected to be more sensitive to environmental conditions) *F. candida.*

Having established that *F. candida* responds differently to soils or substrates of different origins, the second objective was to measure the range of response of 1 d old *F. candida* to agricultural soils representing different phases of conventional and organic potato rotations. A previous study had established that changes in soil quality/health occur throughout the typically extended (5 yr) organic potato rotation sequences (Nelson et al. 2009).

## Materials and methods

### Insects

A laboratory culture of *F. candida* was obtained from the Biological Methods Division of Environment Canada in Ottawa, ON, Canada. Insects were cultured according to ISO (1999) and Environment Canada (2005) protocols on a moistened substrate of 9:1 plaster of Paris: activated carbon powder (50–200 mesh; Fisher Scientific) by weight. The substrate was poured to a depth of 1 cm in clear plastic culture boxes (76 mm H × 152 mm W × 228 mm L) with lids. Stock cultures were kept under continuous darkness at a constant temperature of 20 ± 0.5 °C (BOD Model L127, Sheldon Manufacturing, Oregon). Containers were aerated every three to four days and gently sprayed with double deionized water to remoisten the substrate. Fleischmann's® yeast (*Saccharomyces cerevisiae*) was given *ad lib* and unconsumed yeast was removed weekly to avoid spoilage by fungi and bacteria. Stock culture substrate was renewed every 2–3 months.

Age synchronized cultures of juveniles were obtained by transferring eggs from stock cultures onto pie shaped pieces of plaster using a fine tipped paintbrush dipped in water. Eggs were allowed to hatch for 24 h before removing the plaster pieces containing unhatched eggs. One day old neonates remaining on the plaster with the unhatched eggs were gently brushed into the age synchronized culture boxes.

### Soil series

The body growth, fecundity and survival response of 10 d and 1 d old individual *F. candida* on forest soil was compared to the same parameters on pasture soil, composted manure with sand plus, yeast and sand alone as controls (Table 1). The sand (quartz), technically free of available food, met the criteria of the ISO (1999) standards for artificial soils (particle size 0.05–0.2 mm) (Shaw Resources, Shubenacadie, Nova Scotia). The forest soil was collected in Truro, Nova Scotia (NS), from a deciduous forest undisturbed for 20+ yr. The pasture soil was collected from a field consisting of grass and red clover mixture, managed organically for 15+ yr in Kensington, Prince Edward Island (PE). The composted manure, which consisted of dairy manure mixed with straw, was obtained from the Nova Scotia Agricultural College (NSAC) dairy farm, Truro, NS (Nelson et al. 2009). Sand supplied *ad lib* with yeast pellets provided a high quality food resource (Crouau and Moia 2006; Larsen