GRADUATE AND POSTDOCTORAL STUDIES

McGILL UNIVERSITY

FINAL ORAL EXAMINATION
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

OF

ZHOR ABAIL
NATURAL RESOURCE SCIENCES

Physiological mechanisms for the maintenance of nitrogen stoichiometric homeostasis in earthworms and implications for soil nitrogen dynamics in temperate agroecosystems

February 28, 2018
1:15 p.m

Macdonald Stewart Building, Room MS2-022
McGill University, Macdonald Campus

COMMITTEE:
Dr. T. Geary (Pro-Dean) (Institute of Parasitology)
Dr. J. Head (Chair) (Department of Natural Resource Sciences)
Dr. J. Whalen (Supervisor) (Department of Natural Resource Sciences)
Dr. B. Côté (Internal Examiner) (Department of Natural Resource Sciences)
Dr. G. Sunahara (Internal Member) (Department of Natural Resource Sciences)
Dr. D. Burton (External Member) (Dalhousie University)

Dr. Josephine Nalbantoglu, Dean of Graduate and Postdoctoral Studies
Members of the Faculty and Graduate Students
are invited to attend

ABSTRACT

Earthworms contribute to nitrogen (N) cycling in agroecosystems through the direct release of N from their population, and their indirect effects on soil physical, chemical and biological processes. Despite the large body of literature on earthworm ecology, studies that examine the direct role of earthworms on N cycling from the perspective of ecological stoichiometry are lacking. This knowledge gap needs to be addressed, particularly in temperate agroecosystems where earthworms are the dominant soil fauna based on their biomass. This study sought to provide insights into the physiological mechanisms regulating N stoichiometry in earthworm body, to better understand the stoichiometric interaction between earthworms and their food resources at the individual level, and the implications of crop residue quality on earthworm-mediated N dynamics at the agroecosystem level. First, I investigated whether the endogeic earthworm *Aporrectodea turgida* maintains a strict homeostasis in its body N concentration and C:N ratio in controlled laboratory experiment. This allowed me to evaluate some of the physiological mechanisms *A. turgida* can use to regulate its body N stoichiometry, namely secretion of external and internal mucus, selective ingestion, urine excretion, and *in vivo* gut-denitrification. Second, I conducted a field study on earthworm population dynamics in relation to crop residue quantity and quality, and soil particulate organic matter (POM) during a two-year period in no-till corn-soybean agroecosystems. Finally, I quantified the direct flux of N through the population of *Aporrectodea* spp. in no-till corn-soybean agroecosystems, by summing up N released from earthworms through secondary production and excretion (mucus, urine). As expected, *A. turgida* exhibited strict homeostasis in its body N concentration (11%) and C:N ratio (3.9), regardless of the N content (1.5-5.7%) and C:N ratio(8-29) of the organic materials ingested. Among the physiological mechanisms investigated, only selective ingestion and gut-denitrification are likely to contribute to the conservation of N stoichiometry in the body of *A. turgida*. This implies that in N-poor agroecosystems, earthworms will increase their ingestion rates to acquire the necessary amount of N to maintain their N stoichiometry, However, regardless of their food resources, *A. turgida* appear to maintain similar N excretion rate

from urine and mucus, averaging 609 µg N g^{-1} fw d^{-1}, of which 36 to 84% was recovered in the mineral-N and dissolved organic nitrogen (DON) pools after two days. This finding is consistent with the observation that earthworm presence in temperate agroecosystems enhances N mineralization and plant growth. The field study showed that earthworm abundance and biomass were positively related to the amount of surface residue present in no-till agroecosystems, but were not correlated to the chemical composition of crop residue and the soil POM content during this two-year study. As the stoichiometric interaction between earthworms and their food resources under realistic field conditions were not related to these indicators of crop residue quality, I propose that future characterization of food quality should use more meaningful indicators (e.g., assimilable energy). My estimation of the direct N flux through the population of *Aporrectodea* spp. ranged from 22 to 105 kg N ha^{-1} $year^{-1}$, which may represent 24 to 88% of the recommended N fertilizer requirements of corn in Quebec. I conclude that the direct flux of N through earthworm populations is substantial, and likely contributes to the soil mineral N supply for crop production in no-till agroecosystems of Quebec, Canada. Refining the N fertilization recommendation for non-leguminous grain crops to account for N supply from earthworms has the potential to reduce costs and environmental losses of N.

CURRICULUM VITAE

UNIVERSITY EDUCATION

Doctor of Philosophy January 2014- present
Department of Natural Resource Sciences
Macdonald Campus, McGill University, Sainte-Anne-de-Bellevue, Quebec

MSc. in Agriculture September 2007- September 2009
Institut Agronomique et Vétérinaire Hassan 2, Rabat, Morocco

Diploma in Agricultural Engineering September 2004- September 2009
Specialisation in Soil Sciences
Département des Ressources Naturelles et Environnement
Institut Agronomique et Vétérinaire Hassan 2, Rabat, Morocco

EMPLOYMENT

Principal Engineer January 2015-present
National Institute of Agricultural Research (INRA), Settat, Morocco

Research-Engineer December 2009- December 2014
National Institute of Agricultural Research (INRA), Settat, Morocco

AWARDS

2016: Best Oral Presentation at the Centre SEVE Symposium, Session « Productions agricoles et leurs impacts environnementaux »
2016: 3rd place for best oral presentation at the CSSS annual meeting
2016: CSSS Student Travel Award
2016: GREAT Award
2015: IDB Travel Award
2014: GREAT Award
2014: Centre SEVE Travel Award
2014-2016: IDB Merit Scholarship for High Technology
2011: ICARDA Young Researcher Travel Award

PUBLICATIONS

Abail, Z., Whalen, J.K., (2018). Selective ingestion contributes to the stoichiometric homeostasis in tissues of the endogeic earthworm *Aporrectodea turgida.* Soil Biology and Biochemistry 119C, 121-127.

Abail, Z., Whalen, J.K. (Under review). Corn residue inputs control earthworm population dynamics in a no-till corn-soybean rotation. Applied Soil Ecology.

Abail, Z., Whalen, J. K. (In preparation) Stoichiometric homeostasis, a mechanistic explanation for earthworm-induced nitrous oxide emissions. Proceedings of the Royal Society B.

Abail, Z., Sampedro, L., Whalen, J.K., 2017. Short-term carbon mineralization from endogeic earthworm casts as influenced by properties of the ingested soil material. Applied Soil Ecology 116, 79-86.