



# Do soil organic carbon levels affect potential yields and nitrogen use efficiency? An analysis of winter wheat and spring barley field trials

Myles Oelofse<sup>a,\*</sup>, Bo Markussen<sup>b</sup>, Leif Knudsen<sup>c</sup>, Kirsten Schelde<sup>d</sup>, Jørgen E. Olesen<sup>d</sup>, Lars Stoumann Jensen<sup>a</sup>, Sander Bruun<sup>a</sup>

<sup>a</sup> Department of Plant and Environmental Sciences, Faculty of Science, University of Copenhagen, Thorvaldsensvej 40, 1871 Frederiksberg, Denmark

<sup>b</sup> Laboratory of Applied Statistics, Department of Mathematical Sciences, Faculty of Science, University of Copenhagen, Universitetsparken 5, 2100 Copenhagen Ø, Denmark

<sup>c</sup> SEGES, Agro Food Park 15, 8200 Aarhus N, Denmark

<sup>d</sup> Department of Agroecology, Aarhus University, Blichers Allé 20, P.O. Box 50, 8830 Tjele, Denmark

## ARTICLE INFO

### Article history:

Received 29 April 2014

Received in revised form 23 February 2015

Accepted 23 February 2015

Available online 4 March 2015

### Keywords:

Soil organic carbon

Soil organic matter

Wheat

Barley

Crop productivity

Nitrogen use efficiency

## ABSTRACT

Soil organic carbon (SOC) is broadly recognised as an important parameter affecting soil quality, and can therefore contribute to improving a number of soil properties that influence crop yield. Previous research generally indicates that soil organic carbon has positive effects on crop yields, but in many studies it is difficult to separate the effect of nutrients from the effect of SOC in itself. The aim of this study was to analyze whether the SOC content, in itself, has a significant effect on potential yields of commonly grown cereals across a wider range of soil types in Denmark. The study draws on historical data sets from the Danish national field trials consisting of 560 winter wheat (*Triticum aestivum* L.) trials and 309 spring barley (*Hordeum vulgare* L.) trials conducted over the past 20 and 17 years, respectively. We hypothesised that for these two crops, the potential grain yield, the yield with no fertiliser N application and the N use efficiency would be positively affected by SOC level. A statistical model was developed to explore relationships between SOC and potential yield, yields at zero N application and N use efficiency (NUE). The model included a variety of variables and aimed to elucidate the sole effect of SOC by controlling for potential confounding variables. No significant effect of SOC on potential winter wheat was found, whilst for spring barley, only for the coarse sandy loam soil type was a borderline significantly positive effect of SOC on potential yields found. The relationship between unfertilized plot yields and SOC was positive for winter wheat, although not significant, whilst for spring barley a significant positive effect of SOC was found only for the coarse sandy soil type, and a borderline significant positive effect of SOC was found for the coarse sandy loam soil type. A significant negative relationship was found between SOC and NUE for both winter wheat and spring barley. Based on the large dataset analyzed, we cautiously challenge the importance of SOC in contributing to crop productivity in contexts with similar soils and climate, and we speculate that in situations where nutrient limitation does not occur, SOC levels above 1% may be sufficient to sustain yields. In light of the findings presented in this study, further work should be conducted which can further elucidate the effect of SOC on yields.

© 2015 Elsevier B.V. All rights reserved.

## 1. Introduction

Soil organic matter (SOM) is broadly recognised as an important parameter affecting soil quality (Diacono and Montemurro, 2010; Johnston et al., 2009). Therefore, land use and management systems which maintain or enhance levels of SOM are considered pivotal in ensuring agricultural sustainability and productivity (Lal, 2006). SOM is furthermore of global environmental importance

primarily due to the role that soil organic carbon<sup>1</sup> (SOC) plays in carbon sequestration (Morgan et al., 2010).

Crop yields are influenced by a range of factors including solar radiation, water and nutrient availability and pest and weed pressure (Evans, 1993). Soil organic matter influences soil biological, physical and chemical properties, therefore from an agronomic perspective, SOM is considered important as it can contribute in a variety of ways to improving some of the factors influencing

\* Corresponding author. Tel.: +45 35 33 34 42; fax: +45 35 33 34 60.  
E-mail address: [myles@plen.ku.dk](mailto:myles@plen.ku.dk) (M. Oelofse).

<sup>1</sup> We use the terms SOM and SOC interchangeably. In our analysis, we refer primarily to SOC, whilst in Sections 1 and 4 we use both terms according to how cited references have used the term.

crop yield. SOM has been associated with: better plant nutrition, particularly as a potential source of nutrients, improved soil structure, improved water holding capacity and soil buffering capacity (Johnston et al., 2009; Loveland and Webb, 2003). SOM levels are thus intimately linked to soil parameters central to an economically and environmentally sustainable agriculture (Christensen and Johnston, 1997).

A number of studies have investigated the effect of SOM on yields. Lal, 2006 reviewed the effect of SOC on crop yields, focussing primarily on sub-tropical and tropical countries. For wheat grown in the tropics and sub-tropics, the review found that an increase in SOC levels increases wheat yields, particularly in instances where SOC is depleted (Lal, 2006). In a later review of studies reporting the effect of SOC on crop productivity, Lal, 2010 further demonstrates a positive effect of increasing SOC content on crop yields for a variety of crops and locations (including Russia, China and Argentina). The author, however, stressed that crops' agronomic response to SOC concentration depends on numerous factors such as the active or mineralizable C fraction and managerial inputs (especially of nutrients and water) (Lal, 2010).

The organic manuring experiment in Woburn (Johnston et al., 2009) shows that yields for a rotation of potatoes, winter wheat, sugar beet and spring barley were always larger on soils holding more organic matter, despite equal levels of nitrogen (N) application. Similarly, cultivation of spring barley (Hoosfield continuous Barley experiment) resulted in higher yields on fields with higher levels of SOM for three of four cultivars reported (Christensen and Johnston, 1997; Johnston et al., 2009). The evidence from these experiments is quite variable and suffers from the fact that they are obtained on one location and can therefore be difficult to generalize. In China, soil organic matter has been found to correlate with cereal crop productivity and yield stability across several provinces (Pan et al., 2009), although their analysis did not account for other variables that might explain yield. Diaz-Zorita et al., 1999 and Alvarez et al., 2002 investigated the relationship between wheat yields and SOM in the semi-arid Argentine Pampas. Diaz-Zorita et al., 1999 showed that wheat grain yields (ranging from 1711 to 2233 kg ha<sup>-1</sup>) were significantly correlated with soil water retention and total organic carbon (ranging from 10.6 to 15.6 g kg<sup>-1</sup>) in years when moisture availability was the primary limitation, whilst in years with sufficient rain, wheat yields were correlated with total N and available P contents in the soil. Alvarez et al., 2002 found that SOM content (averaging 45 Mg ha<sup>-1</sup> for 0–20 cm in the experiment) was the most important explanatory variable of wheat yields (ranging from 1000 to 5000 kg ha<sup>-1</sup>); however, other variables which also correlated positively to yield included rainfall and potential mineralizable N. In these experiments, higher SOC content would also be associated with better nutritional status of the soil and therefore the improved yields may be an effect of crop nutrient supply rather than an effect of the SOM itself. Loveland and Webb, 2003 conclude there is some evidence that SOC reduction leads to a reduction in yield potential, although these reductions are small, whilst Körschens et al. (2013, 1998), demonstrate marginal positive effects of SOM on potential yields.

The objective of this study is to analyze the effect of SOC content on potential yields of winter wheat (*Triticum aestivum* L.) and spring barley (*Hordeum vulgare* L.) across a wide range of soil types. We test the hypothesis that potential grain yield, yield with no fertiliser N application and the N use efficiency will be positively affected by SOC level. In this study we define potential yields as the yield of a crop cultivar when grown under non-limiting nutrient availability and normal conditions of water availability and disease control. This means that it is only potential in terms of nutrient availability (Evans, 1993). Nitrogen use efficiency (NUE) is defined in this study as a measure of the increase in kg grain N content per kg N applied (Ladha et al., 2005).

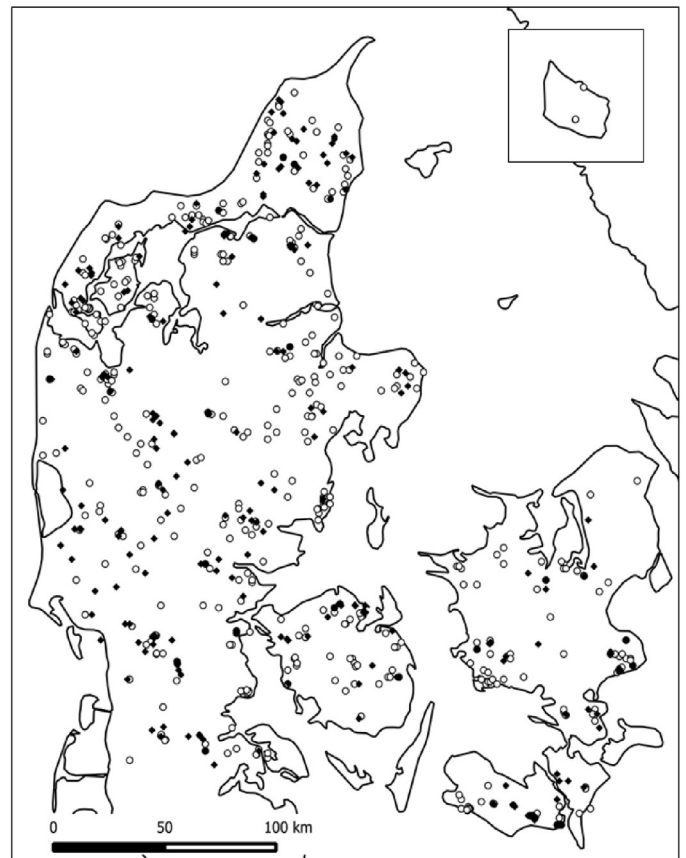


Fig. 1. Overview of the location of experimental sites in Denmark for the winter wheat trials (open circles),  $n = 549$  and spring barley trials (diamonds),  $n = 286$ .

## 2. Materials and methods

### 2.1. Experimental data used for the analysis

Experimental data included in this analysis are from the national field trials conducted in Denmark between 1989 and 2009 by the local branches of the Danish Agricultural Advisory Service. Datasets were extracted from a database of the trials maintained by the Danish Knowledge Centre for Agriculture (Nordic Field Trial System<sup>2</sup>). The primary aim of the field trials included in the analysis was to quantify crop response to N fertilizer applications, relating both to fertilizer type and to determination of the economically optimal N application rate. Yield data were for winter wheat for the period 1989–2009 from 560 farmer field sites in total, and for spring barley for the period 1992–2009 from 309 sites in total. The trials were conducted at different sites each year, geographically covering all climatic regions and soil types in Denmark. The data set thus widely covers Danish arable land. Fig. 1 provides an overview of the location of sites for winter wheat and spring barley in Denmark. Note that we lacked co-ordinates for some sites, therefore the number of sites in Fig. 1 is lower.

### 2.2. Experimental design and treatments

The winter wheat and spring barley experiments were conducted at the respective field sites using a block design with 5 replicates for each treatment with plot sizes ranging from 25 to 35 m<sup>2</sup>. For winter wheat, treatments were different mineral

<sup>2</sup> Accessible online at <https://nfts.dlbr.dk/> (Version 1.0.0.16796).

Download English Version:

<https://daneshyari.com/en/article/4508859>

Download Persian Version:

<https://daneshyari.com/article/4508859>

[Daneshyari.com](https://daneshyari.com)