Soil & Tillage Research 117 (2011) 61–68

Contents lists available at SciVerse ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Analysis of soil characteristics, soil management and sugar yield on top and averagely managed farms growing sugar beet (*Beta vulgaris* L.) in the Netherlands

B. Hanse [a,*], G.D. Vermeulen [b], F.G.J. Tijink [a], H.-J. Koch [c], B. Märländer [c]

[a] B. Hanse, IRS, P.O. Box 32, NL-4600AA Bergen op Zoom, The Netherlands
[b] Wageningen University and Research Centre, Plant Research International, Agrosystems, P.O. Box 616, NL-6700AP Wageningen, The Netherlands
[c] Institute of Sugar Beet Research, Holtenser Landstraße 77, D-37079 Göttingen, Germany

ARTICLE INFO

Article history:
Received 1 February 2011
Received in revised form 8 July 2011
Accepted 24 August 2011
Available online 1 October 2011

Keywords:
Grower performance
Competitiveness
Beta vulgaris L.
Soil compaction
Hydraulic conductivity
Air-filled porosity
Sowing date
Tyre inflation pressure
Sugar yield
Pairwise comparison
Soil management

ABSTRACT

Within the Speeding Up Sugar Yield (SUSY) project, soil management and soil characteristics were investigated as possible causes of yield differences in fields between 26 ‘type top’ and 26 ‘type average’ growers, ‘top’ and ‘average’ performance being based on past yield data. Growers were pairwise selected so that pairs were located in close proximity and on soils of the same texture. In the project years 2006 and 2007, the top growers had 20% ($P < 0.001$) higher sugar yields compared to the average growers.

Top growers made use of comparable equipment, but applied lower tyre inflation pressures and a lower number of field operations for seedbed preparation; their drilling dates were also earlier compared with average growers. This did not result in a significant difference in mean air-filled porosity at field capacity in the topsoil (AP) between grower types, but top growers sowed their beet earlier. The number of fields with a topsoil AP below 10% in the 10–15 cm layer was lower in the group of top growers (13 fields) than in the group of average growers (18 fields).

Direct effects of soil management characteristics on AP could not be distinguished statistically without the factor grower type, but may have remained undetected because both management characteristics and AP appeared to be strongly related to topsoil clay content.

Mean saturated hydraulic conductivity (Ks) in the most dense 5-cm thick subsoil layer (within 25–45 cm depth range) was significantly higher for fields of top growers than for average growers at 0.49 and 0.31 m day^{-1}, respectively. Mean Ks was below a damage threshold level of 0.10 m day^{-1} on 34% of the average growers' fields and on 27% of the top growers' fields. Ks was zero (0.00) m day^{-1} on 9% of all fields. The relative importance of these findings is discussed in this paper. In a multiple regression analysis without the factor grower type, 15.3% of the variability of Ks was explained by a model with the terms of fine sand fraction (50–105 μm) in the subsoil and depth of primary tillage (D_{pt}; m).

A statistical model with AP of the topsoil and Ks of the subsoil could explain 24.9% of the variation in sugar yield for all fields tested, being representative for Dutch sugar beet production, indicating that a good soil structure is needed to obtain high sugar yields.

1. Introduction

The recent reform of the EU sugar market caused a 39.7% reduction in price of sugar beet in 2009 compared to 2006 (EC, 2001; Zeddies, 2006). Studies on the total variable costs in Dutch sugar beet production proved that a cost reduction of up to 20% was possible (Pauwels, 2006), and that sugar yield is independent of the total variable costs (Hanse et al., 2010). Thus, it was concluded that an improvement in competetiveness can be achieved by maximizing sugar yield and optimising costs.

The potential sugar yield in the Netherlands is 23 Mg ha^{-1} (De Wit, 1953) and in Germany 24 Mg ha^{-1} (Kenter et al., 2006) under the given climatic conditions. As the average sugar yield achieved by Dutch growers was 10.6 Mg ha^{-1} in the period 2002–2006, there is great potential for improvement. Additionally, according to records from the sugar industry (Agricultural Service, 2007) a large variation in average grower yields exists within a given region. The pairwise study ‘Speeding Up Sugar Yield’ (SUSY) was conducted to identify the causes of sugar yield differences between neighbouring growers that had high (top grower) and average yields (average grower) under similar conditions of soil and climate. Understanding these causes should facilitate an improvement in the average sugar yield in the Netherlands. In this study, top growers had 20% higher yields compared with the average growers in the same

* Corresponding author. Tel.: +31 0164 274 400; fax: +31 0164 250 962.
E-mail address: hanse@irs.nl (B. Hanse).

0167-1987/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.still.2011.08.008

region (Hanse et al., 2010). Part of the sugar yield difference between top and average growers could be explained by differences in infestation levels of various pests and diseases (Hanse et al., 2011).

The sugar beet crop requires high-quality seedbeds (Håkansson et al., 2006) and is susceptible to topsoil compaction (Koch et al., 2009). Moreover, it benefits from a profile enabling rooting to deep soil layers (Windt, 1995), i.e. it is also susceptible to subsoil compaction. The effects of soil compaction on yield and quality vary between crops and are related to depth and severity, as well as to seasonal effects and crop growth stage (Batey, 2009). For topsoil air-filled porosity at field capacity (AP), a damage threshold of 10% (v/v) is often reported (Bakker and Hidding, 1970; Grable, 1971; Boone et al., 1986). For the saturated hydraulic conductivity (Ks) of the subsoil, a damage threshold of 0.10 m day^{-1} was established (Lebert et al., 2004). Below these damage thresholds, crop yield can be adversely influenced. Therefore, topsoil AP and subsoil Ks were measured in the SUSY pairwise study, and provided data about the actual status of soil structure.

Based on these data, the aim of this paper is to elucidate: (a) relevant soil properties for sugar beet production fields in the Netherlands; (b) the differences in soil management, soil properties and the performance of sugar beet crops managed by type top and average growers; and (c) the relationships between soil management, soil characteristics and subsequent sugar yield. The experiments were carried out as a pairwise study on 104 sugar beet fields in the Netherlands in 2006 and 2007.

2. Materials and methods

2.1. Selection of grower pairs, fields and plots

Two types of growers were selected for the study, top and average growers. A grower was considered a top grower when their sugar yields in the period 2000–2004 were consistently higher than the 75th percentile of the sugar yields in the region. Likewise, a grower was considered average when their sugar yields were consistently between the 25th and 75th percentile of the sugar yields. Pairs were formed by one top and one average grower, with a difference in sugar yield of at least 1.5 Mg ha^{-1} based on the mean yield in the period 2000–2004.

For the study, 26 pairs (52 growers) were selected which participated in both 2006 and 2007. Growers were pairwise selected so that pairs were located in close proximity (average distance between the centres of the investigated fields was 5.5 km) and had similar soil texture and field characteristics (e.g. size, layout, history of reclaiming, crop rotation). Pairs were located all over the Netherlands on various soil textural classes in sugar beet producing regions. For each grower three plots with a size of about 100 m^2 on one field per year were selected, and on which all measurements and observations were conducted. Plots were selected such that they were considered representative for the total field, for example in terms of soil texture, elevation or field history. The plots did not include headlands, field margins, crop nursery tramlines and areas recognisably deviant in crop stand shortly after sowing. The distance between plots depended on the field size, shape and variability, but was typically about 150 m.

2.2. Soil management and soil properties

For all fields a survey on various soil management parameters was conducted regarding tillage and drilling. Data documented by the growers were: rear tyre inflation pressure during primary tillage (P_{pt}), depth of primary soil tillage (D_{pt}), tractor mass (TM_{st}), width ($TW_{st\ front}$ and $TW_{st\ rear}$) and inflation pressure ($P_{st\ front}$ and $P_{st\ rear}$) of front and rear tyres and number of passes for seedbed preparation (n_{st}). All fields studied received primary tillage to an average depth of 28 cm (range 19–43 cm) each year, usually in the form of mouldboard ploughing. The seedbed was prepared by (power) harrowing (mostly restricted to clay soils) or packer rollers combined with primary tillage (only on sandy soils). On sandy soils manure was injected to a maximum of 15 cm depth in the soil in spring. On clay soils manure was injected after the previous crop in autumn, before ploughing. Mineral fertilisers were broadcast in the spring.

Analyses for intrinsic soil characteristics were made at Blgg AgroXpertus (Oosterbeek, the Netherlands). $CaCO_3$, organic matter, clay, silt and sand content and pH–KCl were determined from samples taken with a 1.5 cm auger from the topsoil (0–30 cm) and the subsoil (30–45 cm). For each plot and depth, one composite sample of the topsoil and one of the subsoil were analysed. For all analyses of soil intrinsic characteristics, samples were air dried at 40 °C and sieved through a 2 mm mesh to remove any stones and coarse organic material. Soil was extracted with 1:5 m/V 1 M KCl and pH was measured in the resulting suspension (min. 1 h and max. 3 h). Organic matter content (loss on ignition; %, w/w) was determined by weighing samples (dried at 105 °C) before and after burning at 550 °C in a muffle furnace for 12 h. $CaCO_3$ determination was conducted according to the Scheibler method: after shaking with 3.2% HCl for 1 h, the CO_2 released was captured in a gas burette. Soil texture was determined according to Dutch standard 5753. Soil was sieved in fractions <2 μm (clay), 2–<50 μm (silt), 50–<105 μm (fine sand), 105–<210 μm, 210–<300 μm, 300–<420 μm, 420–<600 μm, 600–<2000 μm and >2 mm.

Soils included in the study were classified as fluvisol and luvisol (clay soil) and podzol and histosol (sandy soils) according to the FAO classification (European Communities, 2005).

Soil structure was characterised in the spring by the total porosity (TP) and AP in the topsoil (10–15 cm), and PR and Ks in the pan layer (subsoil, 25–45 cm). PR was determined by taking 6 penetrations to 80 cm depth per plot but only those in the pan layer were used in the statistical analysis. These measurements were recorded using an Eijkelkamp electronic penetrometer (cone top angle 60 degrees; base area 1.0 cm^2) soon after drilling, when moisture content was expected to be at field capacity. In the Netherlands, field capacity is usually defined as the moisture content at a soil water matric potential of −10 kPa (pF 2), according to Kuipers (1961). To determine TP and AP, the soil was sampled in the 10–15 cm depth layer, early in the growing season (April–June) by taking 8 cores of 100 cm^3 on each plot at random. Equilibration of the samples to −10 kPa soil water matric potential was carried out on a sand box.

To establish Ks on each plot, 7 undisturbed soil cores (of 100 cm^3) were collected from the layer with the highest penetration resistance (PR_{ks}) observed in the soil profile to 60 cm depth (2006) or 45 cm depth (2007), assuming Ks to be lowest in that layer. At sampling, the soil profile was observed to provide a visual means of correcting sampling depth. In some plots, where high penetration resistance was clearly not caused by compaction but by a layer of different soil texture (sandy layer below clayey horizon), the measured Ks was excluded from the statistical analysis (in 2006) or the Ks samples were taken just above the layer with different soil texture (in 2007). Sampling was completed within 4 weeks of PR measurement, independently for each plot. In the lab, Ks was determined according to Klute and Dirksen (1986) using an Eijkelkamp soil water permeameter. The measuring time was set to 24 h maximum.

2.3. Crop characteristics

Sowing date (D_s) and subsequent canopy closure date (D_{cc}) were recorded. D_{cc} was defined as the first date on which sugar