Reduced tillage for silage maize on sand and clay soils: effect on yield and soil organic matter

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Abstract

Maize (*Zea mays*) cultivation for silage has negative impacts on soil and water quality: reduced soil organic matter, nitrate leaching, soil-biota decline, etc. These problems can be caused partly by intensive soil tillage, like ploughing. The suitability of less-intensive tillage alternatives for farmers, in terms of effects on yield and soil quality, is unknown. On three field experiments, two on sandy soils and one on marine clay soil, we compared 'full-field inversion tillage' with two reduced tillage systems: 'full-field non-inversion tillage' and 'strip-cutter'. Reducing tillage intensity in silage maize cropping influenced both yields and soil quality: at two locations yields tended to be reduced, and at two locations soil organic matter content was lower in inversion tillage compared to reduced tillage. The possible implications of reduced soil organic matter mineralisation for nitrogen dynamics are discussed.

Keywords: *Zea mays,* reduced tillage, yield, soil organic matter

Introduction

Traditional continuous cultivation of silage maize is known to have negative impacts on soil and water quality: reduced soil organic matter, nitrate leaching, soil-biota decline, soil degradation and compaction (Van Eekeren *et al.*, 2008). Part of the problems are linked to the intensity of traditional soil tillage (ploughing, spading) and, therefore, less-intensive tillage systems have been developed. In the Netherlands, an increasing number of farmers and contractors are adopting these new practices. Drivers for this adoption are conservation of soil organic matter and soil biota, better harvest conditions (load-bearing capacity) and lower fuel consumption. Reduced tillage systems for silage maize include non-inversion tillage (full-field) and strip-till or strip-cutter (cultivation of the maize row only). The strip-cutter can be used in grassland or another closed crop, the cutter preparing a seedbed for the maize row (10-15 cm width) (www.maisteeltinstroken.nl). In the Netherlands little experimental research has been done to test the suitability of these alternative systems in terms of their effects on yield and soil quality. At three locations, one on marine clay and two on sandy soil, we set up field experiments to compare a number of tillage strategies in silage maize cropping.

Materials and methods

Three experiments were established after grassland in 2009 (Lelystad) and 2012 (Rolde and De Moer) with treatments combining silage maize crops with different tillage and green manure strategies. Key information is given in Table 1. In this paper, we report the results of treatments related to soil tillage: full-field inversion tillage (IT; ploughing in Lelystad and De Moer, and spading in Rolde), full-field non-inversion tillage (NIT) and strip-cutter (SC). Silage yield was measured each year with an experimental plot maize harvester. Dry matter (DM) content was determined to calculate DM yield. Soil samples were taken in December 2014 in the soil layers 0-15 cm and 15-30 cm and soil organic matter (SOM) content was determined by loss-on-ignition (Ball, 1964). Statistical analysis was done for each experiment separately using ANOVA, randomized block design in Genstat 13.3 and a significance level of 5%. For Lelystad, data from 2010-2014 are reported.

Table 1. Overview of the experiments in Lelystad, Rolde and De Moer, the Netherlands.

	Location		
	Lelystad	**Rolde**	**De Moer**
Province	Flevoland	Drenthe	Noord-Brabant
Soil type	Young marine clay	Sand	Sand
Year of establishment	2009	2012	2012
Previous crop	Grassland	Grassland	Grass-clover
Replicates	3	3	4

Results and discussion

In Lelystad, silage maize yields were significantly lower in NIT and SC compared to IT. Furthermore, yields tended to increase in the later experimental years, with high figures in 2014 (Table 2). This tendency was biased by the low yields in 2011 caused by heavy *Kabatiella zeae* infection. Later on, *Kabatiella*-tolerant varieties were used. A change of tillage system brings changes in infection type, and varieties have to be adapted. In Rolde and De Moer, the effect of experiment year interacted with tillage (Table 2). In De Moer for example, the yield of SC was greater than that of IT in the first experiment year, but in the last two years no significant differences were found.

Soil organic matter (SOM) was significantly influenced by soil tillage at both Lelystad and De Moer. In both experiments, SOM was greater in the reduced tillage (NIT or SC) compared to the IT treatment at the 0-15 cm layer, but not in 15-30 cm (Table 3). In contrast to the reduced tillage, no difference in SOM distribution between soil layers was found for the IT treatment. This is clearly an inversion and mixing effect of IT over the 0-30 cm layer. In Rolde, however, where in the IT treatment a spader was used instead of a plough, the SOM mixing was less pronounced. In contrast to Lelystad and Rolde, the treatment effect on SOM in De Moer was still significant over the whole 0-30 cm layer (P=0.031; Lelystad: 0.315; Rolde: 0.507) and represented a difference of 12.4 Mg SOM ha^{-1} when comparing IT with SC. This difference

Table 2. Silage maize yield for inversion tillage (IT), non-inversion tillage (NIT) and strip-cutter (SC), per location and year.[1]

Location	Year	Maize yield (Mg DM ha^{-1})			
		IT	NIT	SC	Mean
Lelystad	2010	16.6	18.1	16.3	17.0 b
	2011	14.6	10.4	11.4	12.1 a
	2012	23.4	20.8	16.9	20.3 c
	2013	17.9	17.1	13.6	16.2 b
	2014	24.2	21.3	20.5	22.0 c
	Mean	19.3 c	17.5 b	15.7 a	17.5
Rolde	2012	17.5 e	16.3 cde	13.1 a	15.6
	2013	16.4 cde	15.0 bc	17.4 de	16.3
	2014	17.1 de	15.5 bcd	14.2 ab	15.6
	Mean	17.0	15.6	14.9	15.8
De Moer	2012	15.3 a	15.4 ab	17.2 bc	16.0
	2013	15.3 a	13.9	13.8 a	14.4
	2014	19.7 d	20.3	18.8 cd	19.6
	Mean	16.8	16.6	16.6	16.6

[1] Where an effect (tillage, year or interaction) is significant, different letters indicate significant difference between numbers within a location.

Table 3. Soil organic matter content for inversion tillage (IT), non-inversion tillage (NIT) and strip-cutter (SC), per location and soil layer.[1]

Location	Layer (cm)	Soil organic matter (g kg^{-1})			
		IT	NIT	SC	Mean
Lelystad	0-15	4.4 b	5.6 c	5.4 c	5.2
	15-30	4.3 ab	4.1 ab	3.7 a	4.0
	Mean	4.4	4.9	4.5	4.6
Rolde	0-15	5.1	5.9	5.4	5.5 b
	15-30	4.3	4.9	5.0	4.7 a
	Mean	4.7	5.4	5.2	5.1
De Moer	0-15	3.6 a	n.d.	4.2 b	3.9
	15-30	3.6 a	n.d.	3.6 a	3.6
	Mean[2]	3.6		3.9	3.8

[1] Where an effect (tillage, layer or interaction) is significant, different letters indicate significant difference between numbers within a location. n.d. = not determined.

[2] The difference between IT and SC in De Moer in 0-30 cm was significant.

over three growing seasons equals ca. 150 kg N ha^{-1} per year from mineralization (N SOM^{-1} ratio of 0.037; Van Eekeren *et al.*, 2008), which is probably lost to the environment under IT as no difference was found in harvested yield (Table 2) or in soil mineral N at the end of the season (data not shown).

Conclusions

Reducing tillage intensity in silage maize cropping can influence both yields and soil quality. Yields tend to be reduced, but the net mineralization of soil organic matter is also reduced.

References

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