Sward lifting in compacted grassland: effects on soil structure, grass rooting and productivity

De Boer H.C.[1], Deru J.G.C.[2] and Van Eekeren N.[2]
[1]Wageningen Livestock Research, De Elst 1, 6708 WD Wageningen, the Netherlands; [2]Louis Bolk Institute, Kosterijland 3-5, 3981 AJ Bunnik, the Netherlands

Abstract

One way to ameliorate compaction in the topsoil (0-30 cm), without destroying the sward, is soil loosening by sward lifting. To explore the potential of this form of non-inversion tillage, we applied this treatment once, either in spring or autumn, to a moderately compacted grassland on a sandy soil and measured the effects on soil structure, grass rooting and productivity for up to two growing seasons. We also explored whether complementary overseeding with *Lolium multiflorum* Lam. would extend the duration of soil loosening effects. Our results show that sward lifting improved soil structure and rooting for at least 10-12 months, but did not result in a consistent or lasting increase in herbage yield or nitrogen (N) uptake. Loosening in spring decreased herbage yield (-27%) and N uptake (-16%) in the following growth period, but these decreases were largely compensated for (herbage yield) or more than compensated for (N uptake) by increases in the next three growth periods. The increase in N uptake in the first growing season (+13 kg N ha^{-1}) was reversed in the second season (-14 kg N ha^{-1}). Loosening in autumn increased herbage yield (+8%) and N uptake (+15%) in the first growth period (after winter), but not in the four growth periods thereafter. Cumulative yield tended to be higher (+4%), supporting the view that soil loosening should be carried out in autumn rather than in spring. The positive effects of loosening on herbage yield and N uptake were explained by a temporary increased soil N mineralization; initial negative effects by mechanical damage to sward and roots. Finally, complementary overseeding did not extend the duration of soil loosening effects.

Keywords: soil compaction, grassland, sward lifting, soil loosening, soil structure

Introduction

Soil compaction is a common problem in permanent grassland. Soil compaction may affect root growth and activity, e.g. through physical impedance and oxygen deprivation, and hence impair crop growth. Compaction of the topsoil layer (0-30 cm) can be ameliorated by sward lifting, a form of non-inversion tillage. Although soil compaction is likely to have negative effects on the production of grassland, little research has been done to assess the effects of amelioration methods. A field experiment by Van Eekeren and Ter Berg (2008) showed (short-lived) positive effects of sward lifting on soil structure, but not on herbage yield. These authors hypothesized that the effectiveness of soil loosening could be enhanced by overseeding (i.e. adding grass seeds to the existing sward), assuming that the rapidly growing roots of seedlings would be more likely to quickly occupy and stabilize the macropores created by soil loosening than the older roots of the existing sward. The objective of the present study was to explore the potential of sward lifting, with and without overseeding, as a method to ameliorate soil compaction.

Materials and methods

The experiment was conducted in permanent grassland on a compacted (based on a high penetration resistance), undrained, water-retaining fine sandy soil in the southern part of the Netherlands (51°61'N, 5°80'E). Treatments were applied either in the late spring (after the first harvest) or early autumn of 2014, and effects were measured in 2014 (2^{nd}, 3^{rd}, 4^{th} and 5^{th} harvests) and 2015 (1^{st}, 2^{nd}, 3^{rd}, 4^{th} and 5^{th} harvests) growing seasons (spring treatments) or the 2015 (1^{st}, 2^{nd}, 3^{rd}, 4^{th} and 5^{th} harvests) growing season (autumn treatments). The field experiment was set up as a randomized complete block design,

with time of treatment (spring or autumn) assigned to two main plots located adjacent to each other. Within each main plot, all treatments (control, soil loosening, overseeding, and soil loosening combined with overseeding) were replicated on five plots (10×2.7 m) in five randomized blocks. Overseeding was carried with a Vredo Agri (Vredo Dodewaard BV, Dodewaard, the Netherlands), sowing Italian ryegrass (*Lolium multiflorum* Lam. cv. Mont Blanc) at a rate of 25 kg ha^{-1}. Soil loosening was carried out with an Evers Agro sward lifter with five shanks, spaced 60 cm apart and fitted with hardened, 20 cm wide winged tines which operate to a depth of 25 cm (Evers Agro BV, Almelo, the Netherlands).

Soil measurements consisted of penetration resistance, root biomass, and a visual assessment of soil structure and rooting. Sward measurements consisted of herbage yield and herbage N uptake. Herbage yield was determined by cutting the grass with a Haldrup grass harvester (J. Haldrup a/s, Løgstør, Denmark). The harvested material was weighed, and samples were oven-dried at 70 °C for 48 hours to determine dry weight and calculate herbage biomass and N uptake. Total N content in the dried samples was determined by a Dumas-based method (NEN 16634-1, 2008). Treatment effects were statistically analysed in pairwise comparison between treatment and control for each of the late spring and early autumn treatments separately, using the ANOVA-procedure in the Genstat statistical package (17th edition) (De Boer *et al.*, 2018).

Results

Soil loosening in spring and autumn reduced soil penetration resistance for at least 10 months and 12 moths respectively, compared to the controls. Soil loosening in spring had no effect on total root biomass (0-40 cm depth) or root biomass per 10 cm soil layer, measured after 1 and 4 months. When applied in autumn, soil loosening also had no effect on total root biomass, as measured after 6 and 12 months. However, after more than 12 months, root biomass was higher in the 10-20 cm and 20-30 cm soil layers of the loosened plots, compared to the controls. Soil loosening in spring had a positive effect on soil structure in the 0-25 cm soil layer for at least 10 months, with the strongest effect observed after 1 month. When applied in autumn, soil loosening also had a positive effect on soil structure in the 0-25 cm soil layer for at least 10 months.

Soil loosening in spring had a significant effect on herbage yield of each of the four growth periods in the first growing season (2014): while yield of the first growth period was lower, the yields of the second, third and fourth growth periods were higher, compared to the controls. Cumulative yield of the first year was not influenced (Table 1). In the second growing season (2015), no effect of loosening was observed on the first, second and third growth periods, but yields of the fourth and fifth growth periods were lower, and cumulative yield tended to be lower in the loosened plots, compared to the controls. When applied in autumn, soil loosening significantly increased the yield of the first following growth period (2015 growing season), but had no significant effect on subsequent growth periods (Table 1). The cumulative yield tended to be higher in the loosened plots, compared to the controls. Soil loosening in spring decreased N uptake during the first following growth period (although this effect was not significant, P=0.19), but tended to increase or increased N uptake during the next three periods, compared to the controls (P=0.07, P=0.01 and P=0.07, respectively). Cumulative N uptake during this first year (2014) was not significantly influenced (Table 2). In the second year (2015), N uptake tended to be higher (P=0.08) during the first growth period, but was lower for the fourth growth period and tended to be lower (P=0.06) for the fifth growth period. Cumulative N uptake in the second year was not influenced. When applied in autumn, soil loosening increased N uptake in the first following growth period (in 2015), compared to the controls. However, N uptake in the next four growth periods was not different from the controls, and no effect was observed on cumulative N uptake.

Table 1. Cumulative herbage yield (kg DM ha^{-1}) of a compacted grassland, as influenced by sward lifting and/or overseeding applied in the spring or autumn of 2014 (n=5).

Time of treatment	Year	Treatment[1]				*P*-value[2]		
		C	L	OS	L + OS	L	OS	L + OS
Spring 2014	2014	8,944	8,603	8,417	8,426	0.40	0.09	0.37
	2015	11,451	11,078	11,836	11,673	0.10	<0.01	0.49
Autumn 2014	2015	11,232	11,523	11,294	11,962	0.09	0.36	0.48

[1] C = control; L = lifting; OS = overseeding.

[2] *P*-values of the main effect for L and OS and of the interaction for L + OS. A difference is significant where $P<0.05$.

Table 2. Cumulative nitrogen uptake (kg N ha^{-1}) in a compacted grassland, as influenced by sward lifting and/or overseeding applied in the spring or autumn of 2014 (n=5).

Time of treatment	Year	Treatment[1]				*P*-value[2]		
		C	L	OS	L + OS	L	OS	L + OS
Spring 2014	2014	217	230	–[3]	–	0.16	–	–
	2015	275	261	277	280	0.23	0.04	0.09
Autumn 2014	2015	265	272	277	292	0.14	0.03	0.56

[1] C = control; L = lifting; OS = overseeding.

[2] *P*-values of the main effect for L and OS and of the interaction for L + OS. A difference is significant where $P<0.05$.

[3] Not determined.

Discussion and conclusion

The positive effects of sward lifting on soil structure and rooting in the compacted grassland of our study persisted over two growing seasons, but did not result in consistent or lasting herbage yield increases. Our results indicate that soil-loosening experiments should measure not only herbage yield but also herbage N uptake. Longer-term N uptake patterns enable to distinguish whether yield increases are caused by temporary increased N mineralization, or by other factors, such as improved root growth. Furthermore, our results indicate that grassland experiments in which soil N dynamics are influenced should run for at least two growing seasons, to account for potential compensatory effects or reversal of effects after the first growing season. Lastly, our study showed that complementary overseeding did not extend the duration of soil loosening effects. Apparently, new root growth from the existing sward was effective enough to stabilize these effects (De Boer *et al.*, 2018).

Acknowledgements

We thank the Dutch Dairy Board (ZuivelNL) for funding the experimental work and all parties involved in the Public Private Partnership 'Forage Production and Soil Quality' for funding the reporting.

References

De Boer H.C., Deru J.G.C. and Van Eekeren N. (2018) Soil loosening to ameliorate compaction and increase the productivity of permanent grassland. *Soil Tillage* 184, 317-325.

Van Eekeren N. and Ter Berg C. (2008) Grassland aeration does not increase herbage yield, yet (in Dutch). *V-focus*, August edition, AgriMedia, Wageningen, the Netherlands, pp. 26-28.

2019 EGF EUCARPIA

Joint Symposium | Zurich, June 24–27

Improving sown grasslands through breeding and management

Edited by

O. Huguenin-Elie
B. Studer
R. Kölliker
D. Reheul
M. Probo
P. Barre
U. Feuerstein
I. Roldán-Ruiz
P. Mariotte
A. Hopkins

EUCARPIA

EGF

Volume 24
Grassland Science in Europe