Maize in permanent grassland: effects of strip tillage and mechanical weeding on soil properties and yields

Deru J.[1], Struyk P.[1] and Pol H.[2]
[1]Louis Bolk Institute, Kosterijland, 3–5, 3981 AJ Bunnik, the Netherlands; [2]Henk Pol Mechanisatie, 7975 PD Uffelte, the Netherlands

Abstract

Silage maize is a valued crop in grassland-based dairy farming due to its high yield and feeding value. However, the delivery of ecosystem services (biodiversity, soil quality, carbon sequestration etc.) is greatly reduced in maize, compared to permanent grassland. To combine the ecosystem services of maize and grassland, a cropping system was developed for silage maize sown in living permanent grassland. In a field experiment, grass was superficially mulched, either full-field or in strips, maize was sown and weed control was carried out mechanically, both full-field and in strips. The control included chemical full-field grass killing and chemical weed control, without soil tillage. Measurements at the end of the growing season show no significant treatment effects in maize yield and soil quality, but clear negative effects of superficial tillage on earthworm biomass. We conclude that in a fertile soil, silage maize can be grown without use of herbicides and that a strip of permanent grassland reduces the negative impact of superficial tillage for the earthworm population.

Keywords: minimal tillage, herbicide-free maize, grassland, soil quality, earthworms

Introduction

Minimal tillage can be used to reduce the loss of soil quality in dairy farming when silage maize is grown after grassland. Reduced tillage, combined with herbicides to control grass and weed growth, shows similar maize yields compared to ploughing, but higher numbers of earthworms and faster water infiltration (Deru *et al.*, 2015; Sleiderink *et al.*, submitted; Van Agtmaal *et al.*, 2020). By leaving out herbicides, such cropping systems could further gain in biodiversity, nutrient retention and water infiltration due to the permanent living soil cover, as shown by Struyk *et al.* (2021). However, loss of maize yield due to water and nutrient uptake by the grass needs to be minimized, and should be in balance with gains in ecosystem services. As a next step, (strip-) mulching and mechanical weeding techniques were used as a new combination in a field experiment. Our objective was to compare maize yield and soil biological, chemical and physical properties of chemical (full-field or strip) versus mechanical (full-field or strip) methods of grass and weed control in maize sown with minimal tillage in permanent grassland.

Materials and methods

A randomised block experiment with five treatments (Table 1) in four replicates was carried out in 2023 on a permanent grassland of a dairy farm on sandy soil in Ruinerwold, Drenthe. The grassland had been fertilized in spring with 20 m^3 ha^{-1} cattle slurry and was mown (1st of May, 1.7 t DM ha^{-1}, 53 kg N ha^{-1}) prior to the experiment. Before sowing, the grassland was treated either with glyphosate, with a full field superficial mulch machine mixing 3-4 cm of topsoil with the grass sod, or with an adapted version of this machine leaving a strip of 15 cm permanent grassland between the maize rows (Table 1). Maize (Exelon, KWS), was sown (8th of May; 75 cm row distance) in all treatments by minimal tillage with a combined strip-cutter and subsoiler (20 cm deep, 10 cm broad). Artificial N fertilizer at 30 kg N ha^{-1} was provided in the row. Weed control (May-June) was carried out either with herbicides (8th of June, full-field for 'chem+chem' and 'mulch+chem' and in the maize row for 'strip+chem') or with a combination of harrowing (full-field) and hilling (strips).

Table 1. Systems of grass and weed control used per treatment with minimal tillage maize

Treatment	Grass control at start (May)	Weed control after sowing (May–June)
Chem+chem	Chemical (glyphosate)	Chemical (1×cocktail; full-field)
Mulch+chem	Full field mulching	Chemical (1×cocktail; full-field)
Mulch+mech	Full field mulching	Mechanical (5×harrowing, then 2×hilling)
Strip+chem	60 cm mulching, 15 cm grass left	Chemical (1×cocktail; in maize row)
Strip+mech	60 cm mulching, 15 cm grass left	Mechanical (5×harrowing, then 2×hilling)

N mineral content of the top 30 cm soil was measured during the growing season in May, June, August and at harvest (September). At harvest, N mineral was also measured in 30–60 cm and 60–90 cm soil depth. Other soil measurements were carried out at the end of the growing season (28th of August): penetration resistance, soil structure, water infiltration and earthworm biomass. The central two maize rows were harvested (21st of September), chopped, weighed and dry matter content and feeding value were determined in a fresh sub sample by NIRS (Eurofins, Wageningen). Genstat (v. 23) was used for data analysis.

Results and discussion

Maize yield in 'strip+mech' was 12% lower than in the control ('chem+chem'), although the overall treatment effect was not significant (P=0.16, Figure 1) due to large variation between replicates. Protein content was lowest in the treatments with a strip of grass left between the rows (Table 2), possibly indicating N uptake competition by the grass. There were no treatment differences in either soil mineral N content throughout the season or in N uptake. Soil mineral N was highest in June, and the residual amount at harvest in September in the 0–90 cm layer was still high, between 79 and 109 kg ha^{-1}. A rough N balance indicated that the soil N supply must have been high, ca. 150 kg N ha^{-1}, even without soil tillage. Local variation across the experiment in the soil N supply and N uptake by regrowing grass under the maize may have contributed to the variation in maize yields between replicates. This calls for further development of mulching and weeding techniques.

Soil structure, rooting density, penetration resistance and water infiltration rate were not affected by the treatments (Table 2) but earthworm biomass was (Figure 1).

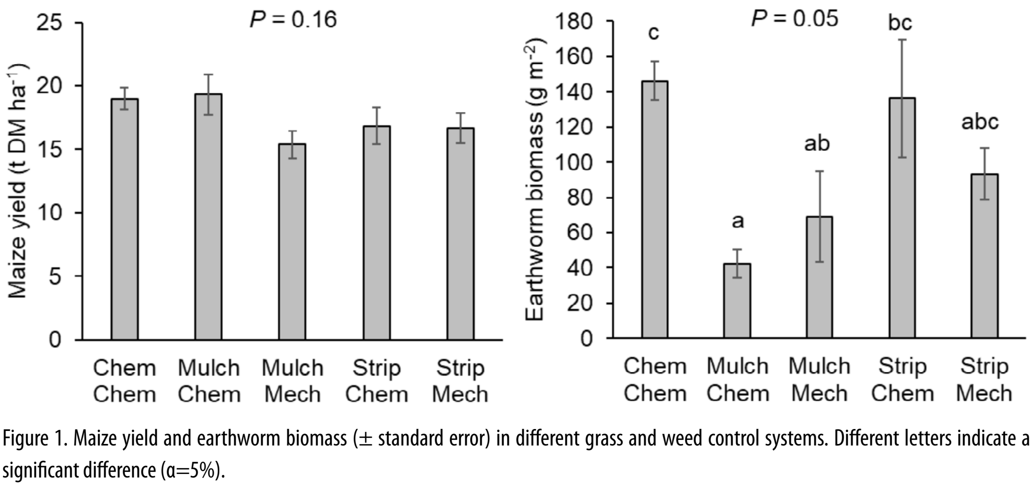

Figure 1. Maize yield and earthworm biomass (± standard error) in different grass and weed control systems. Different letters indicate a significant difference (α=5%).

Table 2. Maize and soil parameters in different grass and weed control systems.

Parameter	Unit	Chem+chem	Mulch+chem	Mulch+mech	Strip+chem	Strip+mech	*P*-value
Maize yield	t DM ha^{-1}	19.0	19.3	15.4	16.8	16.7	0.16
Protein content	g kg^{-1}	68.3 ab	70.0 bc	71.0 c	66.5 a	67.6 ab	0.04*
Starch content	g kg^{-1}	436.8	429.2	424.5	451.0	436.4	0.35
N uptake	kg N ha^{-1}	207.2	216.6	174.6	179.6	180.7	0.19
N-min 0–30 cm May	kg N ha^{-1}	59.0	n.d.	71.0	78.5	42.8	0.14
N-min 0–30 cm Jun	kg N ha^{-1}	180.0	n.d.	145.0	132.0	133.0	0.39
N-min 0–30 cm Aug	kg N ha^{-1}	23.8	n.d.	23.8	28.8	20.0	0.66
N-min 0–30 cm Sep	kg N ha^{-1}	62.8	n.d.	55.2	70.5	51.0	0.57
N-min 0–90 cm Sept	kg N ha^{-1}	108.8	n.d.	79.2	104.7	85.0	0.47
Soil crumbs 0–20 cm	%	32.5	25.0	30.8	27.5	32.5	0.42
Root density 0–20 cm	Score 1-10	5.4	5.2	6.3	5.9	4.9	0.23
Pen.res. 0–30 cm	kPa	2.00	1.99	2.02	2.09	2.20	0.81
Pen.res. 0–10 cm	kPa	1.07	1.18	1.05	1.06	1.18	0.33
Water infiltration	mm min^{-1}	4.13	7.00	5.08	4.83	3.25	0.40

*Significant value (P<0.05).

There was a clear negative effect on earthworms of mulching, compared with chemical grass killing. Biomasses of the full chemical versus full field mulching correspond to those in Van Agtmaal *et al*. (2020) who compared a full chemical minimal-till system with full field spading in a similar grassland. Thus, superficial mulching had the same negative effect as spading to 20 cm. However, there was a higher biomass where the sod was partly left intact (strip versus full field mulch). After maize sowing, whether the weeds were controlled mechanically or with herbicides had no effect on earthworm biomass.

The experiment of Struyk *et al.* (2021) found clearer positive effects of leaving out herbicides for soil mineral N and earthworms than in the present study, but the yields of the herbicide-free maize were lower. We explain these differences by the more effective weeding in 2023, resulting in less difference in grass cover between chemical and mechanical treatments. In both years, minimal overseeding (without tillage) after the maize harvest in all treatments was enough to restore the grassland with good quality grasses.

Conclusion

We conclude that in a fertile sandy soil, silage maize can be grown in permanent grassland without use of herbicides with only moderate yield loss. A living strip of permanent grassland reduces the negative impact for the earthworm population of superficial tillage. With a novel combination of techniques in a grass-maize rotation, the yield potential of silage maize can be retained with less loss of the ecosystem services delivered by grassland.

Acknowledgements

The experiment was part of the PPS-project *Innovatieve maisteelt – op weg naar chemievrij, minder uitspoeling, biodiverser*; all partners are acknowledged for their contributions.

References

Deru J., van Schooten H., Huiting H. and van der Weide R. (2015) Reduced tillage for silage maize on sand and clay soils: effect on yield and soil organic matter. *Grassland Science in Europe* 20, 398–400.

Sleiderink J, Deru J., van der Weide R. and van Eekeren N. *Soil and Tillage Research*, submitted.

Struyk P., Deru J., Van Agtmaal M. and Pol H. (2021). Chemievrije maisteelt in grasland. *V-focus* (mei), 12–17.

Van Agtmaal M, Deru J, Struyk P and Pol H (2020). Maisteelt na grasland met de OSP. *V-focus* (januari), 26–29.

The Netherlands 9-13 June

EGF 2024

Why grasslands?

Edited by

C.W. Klootwijk
M. Bruinenberg
M. Cougnon
N.J. Hoekstra
R. Ripoll-Bosch
S. Schelfhout
R.L.M. Schils
T. Vanden Nest
N. van Eekeren
W. Voskamp-Harkema
A. van den Pol-van Dasselaar

EGF

Volume 29
Grassland Science in Europe