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Effect of destruction and burial dates of Cover Crops on Runoff, Erosion, organic carbon losses and phosphorus transfer in a maize cropping system

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Abstract

L'objectif de la présente étude est de déterminer l'impact des dates de destruction et d'enfouissement de deux cultures de couverture hivernales sur le ruissellement (R), l'érosion (E), les pertes en phosphore total (P) et en carbone organique (C) pendant l'interculture et durant la culture principale de maïs sur un sol limoneux et sablo-limoneux en Belgique. La première année d'expérience a montré que, durant l'interculture, les couvertures ont réduit R, E et P de 90 %. Durant la culture de maïs suivante, le site limoneux a révélé un effet résiduel significatif entre traitements : une destruction et enfouissement hâtif a diminué R de 63 % et E, P et C de 94 %, contre 95 % et 97 % pour une destruction et enfouissement tardif. Il semble qu'associer une destruction précoce avec un enfouissement tardif est le moyen le plus efficace de réduire les risques d'érosion tout en préservant les rendements en maïs.

1. Introduction

In Wallonia (Belgium), fields planted with Spring row crops (sugarbeet, potato, maize, chicory) are particularly prone to runoff and soil erosion by water (Bielders *et al.*, 2003). To reduce these problems, planting cover crops is an admitted efficient solution. Indeed, it ensures a soil cover during the winter. It may possibly also improve the soil structure after its burial. However, little information exists about the optimal cover crop destruction and burial dates with respect to erosion control. The aim of the present study is to determine the impact of destruction and burial dates of 2 common cover crops on runoff, erosion and losses of phosphorous and organic matter, as well as on the yields of the subsequent maize crop.

2. Materials and methods

A fully randomized, continuous maize cropping experiment with three combinations of winter cover crop destruction and burial dates repeated 3 times and 3 control plots was carried out on a loamy soil with an average 8 % slope (Nodebais) and on a sandy loam soil with an average 12 % slope (Bonlez). Two species of winter cover crops, rye (Secale cereale) and the Italian ryegrass (Lolium multiflorum), were sown on 1 October 2004 and two factors of management were considered: the destruction date of the cover crop and its date of burial (table 1). The maize crop following the cover crop was sown on 18 May 2005 and was harvested on 9 October 2005.

Table 1: Cover crop destruction dates and burial dates in 2005

Destruction date of the cover crop	**Burial date**
Mid - march D1	40 days later D1B1
	60 days later D1B2
Mid - april D2	40 days later D2B2

Runoff and erosion were measured by means of 90 m² runoff plots on control and rye plots during the winter period and on plots previously covered by rye, ryegrass and on the control plots during the maize season. Total phosphorus, labile phosphorus (maize season only) and organic carbon content (maize season only) was determined in the top 10 cm of the soil and in the eroded sediments for certain erosive events. The contribution of rill erosion to total erosion was assessed on the basis of the volume of rills and a fixed value of bulk density.

Vegetation cover and above ground biomass of the cover crop was estimated monthly. Total above and belowground biomass of the cover crop was evaluated before destruction. Maize development and yield were determined.

ANOVA ($\alpha = 0.05$) was performed by means of the SAS 9.1.3 software. In the absence of normality of the data, the criteria of normality and homogeneity of the variances of the residuals were selected to impose a logarithmic transformation. Treatment averages were compared with the Tukey test.

3. Main results

3.1 Vegetation cover, runoff and erosion

The ryegrass and rye cover rates showed a similar evolution and were already considerable at the beginning of the winter. (respectively 65 % et 45 % in Bonlez and Nodebais). The total biomass at the time of the first destruction was appreciably lower (270 g/m2 in Bonlez and 155 g/m2 in Nodebais) than at the time of the second destruction (588 g/m2 in Bonlez and 691 g/m2 in Nodebais).

During the cover crop period (24/11/2004 – 18/05/2005), we observed that the covered plots reduced runoff by more than 95% (p value Bonlez = 0.0005, p value Nodebais < 0.001) and erosion by more than 98% (p value Bonlez = 0.004, p value Nodebais = 0.001) at each site compared to the control (Fig. 1). Furthermore, for the totality of the cover crop season, the mean runoff coefficients of the control plots were 27 % in Bonlez and 20 % in Nodebais against 0.9 % and 0.5 % for the covered plots in Bonlez and Nodebais, respectively. The higher erosion rates on control plots than under cover resulted both from a higher runoff and a 3 to 5 times higher sediment concentration. Rill erosion represented 37 % of total erosion in Bonlez and 67 % in Nodebais.

The results during the maize cropping season (18/05/2005 – 7/10/2005) were contrasted: no persistent effect of the rye cover in Bonlez as opposed to Nodebais where a significant (pvalue = 0.011) residual effect of the cover crops on runoff and erosion was noted (Fig. 1). Among the previously covered plots in Nodebais, Anova revealed that treatments

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D1B1 experienced higher runoff and erosion than D2B2 (p value = 0.007). Both in Bonlez and Nodebais, Anova did not reveal a significant difference between rye and ryegrass. The runoff coefficients of the 2 sites were not statistically different (p value = 0.313).

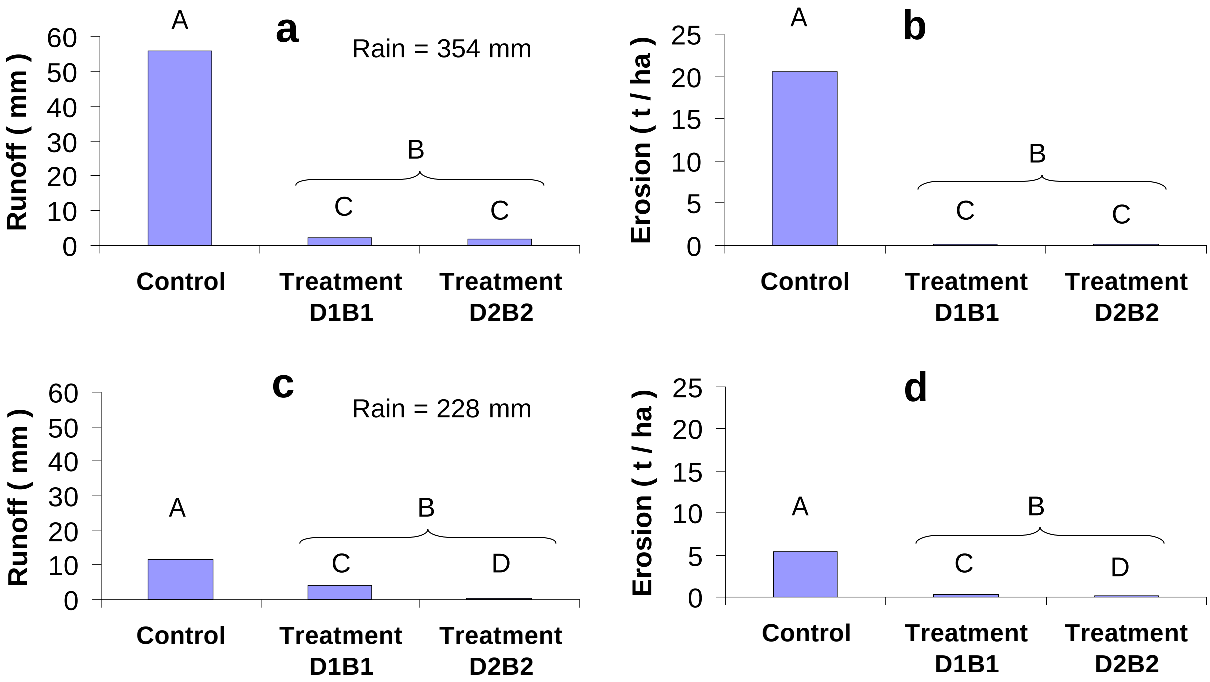

Figure 1: (a) and (b): runoff and erosion rates during the cover crop period in Nodebais (24/11/2004 – 18/05/2005). (c) and (d): runoff and erosion rates during the maize cropping season in Nodebais (18/05/2005 – 7/10/2005). Means with the same letter are not significantly different.

3.2 Phosphorus and organic matter losses

During the cover crop period, at each site, we observed no difference between the total phosphorus concentration in the sediments of the covered plots and the control plots. These concentrations were significantly higher at Bonlez than at Nodebais (Bonlez = 1742 mg/kg, Nodebais = 1418 mg/kg, MSD = 288.6 mg/kg) due to a higher soil P content. As a result of higher erosion rates, the control plots experienced higher P losses than covered plots ({Bonlez: covered plots = 0.04 kg/ha, control plots = 4.30 kg/ha, MSD = 1.962 kg/ha}, {Nodebais: covered plots = 0.04 kg/ha, covered plots = 6.11 kg/ha, MSD = 2.776 kg/ha}).

During the maize cropping season, there were no differences between control and previously covered plots in terms of total phosphorus (P_{tot}), labile phosphorus (P_{lab}) and organic carbon (C_{org}) contents. These contents were higher at Bonlez than at Nodebais. Losses were significantly different (p value = 0.009) between control and previously covered plots at Nodebais only ({P_{tot} : covered plots = 0.2 kg/ha, control plots = 5.5 kg/ha, MSD = 3.51 kg/ha}, { P_{lab} : covered plots = 0.02 kg/ha, control plots = 0.61 kg/ha, MSD = 0.401 kg/ha},{C_{org} : covered plots = 2.7 kg/ha, control plots = 70.9 kg/ha, MSD = 46.55 kg/ha}). At Nodebais only, treatment D1B1 was significantly different from D2B2 ({P_{tot} : D1B1 = 0.3 kg/ha, D2B2 = 0.1 kg/ha, MSD = 0.15 kg/ha}, { P_{lab} : D1B1 = 0.04 kg/ha, D2B2 = 0.01 kg/ha, MSD = 0.015 kg/ha }, { C_{org} : D1B1 = 4.3 kg/ha, D2B2 = 1.3 kg/ha, MSD = 1.75 kg/ha }).

3.3 Maize yield

We observed a significant interaction between the cover crop species and the treatment in Bonlez (pval = 0,0439 / RD1B1 = 14.8 t/ha (ab), SD1B1 = 16.8 t/ha (a), RD1B2 = 17.3 t/ha (a), SD1B2 = 17 t/ha (a), RD2B2 = 12.4 t/ha (b), SD2B2 = 16 t/ha (a), Control = 16.1 t/ha (a)) but no significant treatment effect in Nodebais.

4. Discussion

During the cover crop season, runoff (not exceeding 0.3 l/m2) and erosion (less than 0.3 t/ha) rates on the cover crop plots were very low compared to the control plots. This was linked to the high cover rates at the beginning of winter (see 3.2), which may have reduced surface crusting, increased hydraulic roughness and stabilised the topsoil through a dense rooting system. The control plots ran off and eroded themselves clearly higher than the American standard of 10 t ha-1year-1 to 11 t ha-1year-1. During the maize season a strong residual effect of the cover crops on runoff and erosion was observed at Nodebais but not at Bonlez. This difference among sites was attributed to the fact that a very large fraction of total runoff and erosion at Nodebais resulted from a single intense rainfall event at the end of the maize cropping season, event which was not observed at Bonlez. At Nodebais, runoff and erosion on early destruction – early burial treatment (D1B1) was significantly higher than on the late destruction – late burial treatment (D2B2). Based on this first year of results, associating late destruction and late burial may constitute the best protection against erosion during the maize season.

Regarding maize yield, we observed on each site the same sequences: D1B2 > C > D1B1 > D2B2. The strong maize yield reduction following late destruction and late burial of the cover crops (D2B2) may be explained by nitrogen immobilization and poorer seedbed preparation in the presence of large quantities of undecomposed biomass. Associated with an earlier destruction (D1 = mid-march), the late burial (B2) had no negative impact on the maize yield compared to treatment D1B1. Although there were no runoff and erosion measurements for treatment D1B2, maintaining cover crop residues longer at the soil surface should reduce erosion during the cover crops season. The combination of a sandier soil with lower water holding capacity with a higher water uptake by ryegrass and dryness at the time of maize sowing may explain the lower maize yield following ryegrass compared to rye in Bonlez.

5. Conclusions

Based on these preliminary results, it appears that associating early destruction and late burial of cover crops is the most appropriate treatment for reducing runoff, erosion, P and OC losses while preserving the maize yields.

6. Bibliography

Bielders, C., Ramelot, C. et Persoons, E., 2003. Farmer perception of runoff and erosion and extent of flooding in the silt-loam belt of the Belgian Walloon Region. Environmental Science and Policy 6 : 85-93.