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ROLLER-CRIMPING AS AN ALTERNATIVE TO INCORPORATION OF AGRO-ECOLOGICAL SERVICE CROPS CHANGES NITROGEN DYNAMICS IN ORGANIC CABBAGE PRODUCTION UNDER NORTHERN AND WESTERN EUROPEAN CONDITIONS

Margita Hefner[*1], Stefano Canali[2], Koen Willekens[3], Peter Lootens[3], Pauline Deltour[4], Annelies Beeckmann[4], Donnatienne Arlotti[5], Kalvi Tamm[6], Ingrid Bender[7], Hanne L. Kristensen[1]

[1]Food Science, Aarhus University, Aarhus, Denmark, [2]Consiglio per la Ricerca in Agricoltura e l'analisi dell'Economia Agraria, Centro di ricerca Agricoltura e Ambiente (CREA-AA), Rome, Italy, [3]Plant Sciences Unit, Institute for Agricultural, Fisheries and Food Research, Merelbeke, [4]INAGRO, Rumbeke-Beitem, [5]Walloon Agricultural Research Centre, Gembloux, Belgium, [6]Agrotechnology, [7]Jogeva Plant Breeding, Estonian Crop Research Institute, Jogeva, Estonia

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Abstract: Agro-ecological service crops (ASCs) are used to improve organic vegetable production in terms of weed suppression, nitrogen (N) recycling, or addition of N through symbiotic N_2 fixation by legumes. Full incorporation (FI) of ASCs is commonly conducted to terminate ASCs, but alternative termination can be obtained by roller-crimping (RC) in reduced tillage systems. Field experiments were conducted in Estonia, Denmark, and at three locations in Belgium during two growing seasons (autumn 2015-2017) to investigate the effect of ASC termination method (FI and RC) and ASC species (pea, pea/cereal mixtures and cereals), compared with a bare soil control, on soil mineral N content, cabbage yield and N accumulation. Cabbage yield and N accumulation were reduced under RC compared to BS and FI in a majority of cases mainly due to reduced soil mineral N availability, in some cases owing to a later ASC termination time. Furthermore, slower mineralisation of soil organic matter and ASCs at the soil surface contributed to the yield reduction under RC as compared with FI. Cabbage yield could be maintained under RC at standard fertilisation rate following pea ASC in Denmark. The RC system needs further investigation to improve N availability to the succeeding crop before it can be implemented in organic vegetable production.

Introduction: Agro-ecological service crops (ASC: green manure, catch or cover crops) are widely used in organic agriculture. However, challenges exist in accounting for the nitrogen (N) supply from the ASC to the cash crop, as the amount of N supply depends on the species employed. Legumes have a low C/N ratio and decompose faster than cereals, whereas cereals are better in scavenging soil N than legumes. Growing a mixture of legume/cereal has therefore been proposed as the best strategy to recycle N within the system (Fageria et al., 2005). Interest in reduced tillage techniques is rising and roller-crimping ASCs provides an alternative to traditional incorporation of ASCs as green

manure. However, roller-crimping application within vegetable production is limited and N management can be challenging due to N shortage in this reduced tillage system.

Material and methods: Field experiments were conducted at five locations in three countries, in Estonia, Denmark, and Belgium (East Flanders, West Flanders and Wallonia) during two growing seasons (autumn 2015-2017). The experiments were conducted using complete block designs with two treatment factors, which were (1) ASC species and (2) the termination method of ASCs. The ASC species tested included winter pea (*Pisum sativum* L.), winter cereals (rye (*Secale cereale* L.) or barley (*Hordeum vulgare* L.)) and/or a 50/50 mixture of pea and cereal. The ASC termination treatments were full incorporation (FI) by tillage of the ASC as green manure and roller-crimping (RC) of the ASC. Tilled bare soil served as the control. The trial in Estonia included ASC termination as the only factor. Termination time of ASCs differed between treatments in the three Belgian locations, with 3-5 weeks later termination by RC than by FI, whereas termination time was the same for both treatments in Estonia and Denmark. In Wallonia, the experiment failed in 2016. The ASCs were sown in the previous autumn and terminated in the spring. White cabbage (*Brassica oleracea* L.) was transplanted in June. Soil mineral N was measured at ASC termination or at cabbage transplanting and ASC and cabbage biomass and N content were assessed at ASC termination and at harvest in the autumn, respectively.

Results: N accumulation of ASCs at termination was higher for RC compared with FI in East Flanders, for pea/rye in West Flanders and for pea/barley in Wallonia in 2017 (Figure 1). However, termination did not affect N accumulation of pure cereals (i.e. rye and barley in West Flanders and Wallonia). Pea accumulated more N (106 kg N ha^{-1}) than pea/rye (64 kg N ha^{-1}) in Denmark in 2016 (results not shown).

Soil mineral N in 0-0.9 m depth was generally highest in bare soil, followed by FI and lowest in RC at the time of cabbage transplanting in all locations (Table 1). Soil mineral N was not measured at planting but at ASC termination in Denmark, where it was highest in bare soil (170 and 226 kg ha^{-1}), followed by pea (103 and 237 kg ha^{-1}) and lowest in pea/rye (67 and 100 kg ha^{-1}) in 2016 and 2017, respectively.

Cabbage N accumulation was generally highest in bare soil, followed by FI (in Denmark in 2016, Estonia in 2017, East Flanders in 2016 and 2017 and in Wallonia in 2017), or it was equal between bare soil and FI (in Estonia in 2016 and in West Flanders in 2017). ASC species affected cabbage N accumulation by resulting in higher values following pea (153 kg N ha^{-1}) than rye (118 kg N ha^{-1}) in West Flanders in 2016. Similar results were obtained in Denmark in 2017, where cabbage following pea had a higher N accumulation (227 kg N ha^{-1}) than following pea/rye in (130 kg N ha^{-1}) (Hefner et al., submitted).

Table 1. Soil mineral N (kg ha^{-1}) at the time of transplanting in 2016 and 2017 in 0-0.9 m depth in Estonia and East Flanders, in 0-0.6 m depth in West Flanders, and in 0-0.3 m in Wallonia. Soil mineral N was not measured in Denmark at this time. RC = roller-crimping, FI = full incorporation. Mean values are followed by standard error. Different lower case letters indicate significant differences for location and year separately at $P < 0.05$.

Country	Year	RC	FI	Bare soil
Estonia	2016	33 ± 6 ^{b}	38 ± 4 ^{b}	56 ± 2 ^{a}
	2017	14 ± 2 ^{b}	14 ± 2 ^{b}	26 ± 3 ^{a}
East Flande	2016	25 ± 3 ^{b}	58 ± 4 ^{a}	50 ± 4 ^{a}

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	2017	35 ± 1 [b]	69 ± 5 [a]	67 ± 8 [a]
West Flanders	2016	45 ± 16 [c]	80 ± 9 [b]	162 ± 31 [a]
	2017	16 ± 3 [c]	64 ± 6 [b]	100 ± 8 [a]
Wallonia	2017	9 ± 1 [c]	28 ± 2 [b]	58 ± 3 [a]

Discussion: Rye needs to reach anthesis for efficient termination with a roller-crimper (Mirsky et al., 2009) and was therefore postponed 3-5 weeks under RC compared with FI in all Belgian locations. This prolonged growth period resulted in more N uptake and/or N fixation by the pea/cereal mixtures under RC (Figure 1). However, the prolonged ASC growth under RC also reduced soil mineral N availability at transplanting, compared with FI and bare soil (Table 1). Reduced soil mineral N availability under RC may also have been an effect of slower mineralisation of soil organic matter and ASC plant material in the reduced tillage system. As a result, cabbage N accumulation was lower under RC than FI and bare soil.

Due to the N fixing ability of pea, N accumulation of pea/cereal mixtures was higher than N accumulation of rye in RC in West Flanders and Wallonia. Likewise, pea accumulated more N than pea/rye in Denmark in 2016. Consequently, soil mineral N was higher in pea than pea/rye in Denmark in both years. The higher the percentage of pea in the ASC composition, the higher the N accumulation of the following cabbage, which was found in West Flanders in 2016 and in Denmark in 2017.

Overall, RC showed major yield reductions in the first and second year after conversion from conventional tillage and incorporation of ASCs under Northern European conditions. However, cabbage yield and N accumulation were similar between RC and bare soil in one case: when pea was used as an ASC species and when fertilization was increased to standard application rates in Denmark in 2017 (Hefner et al., submitted).

The potential of RC adoption as an alternative to conventional tillage will depend on the ability to find solutions for the limited N availability in this system, which may include increased legume proportions in the ASC composition, increased fertilization rates in the first years after implementation and an improved timing between ASC termination and crop transplanting.

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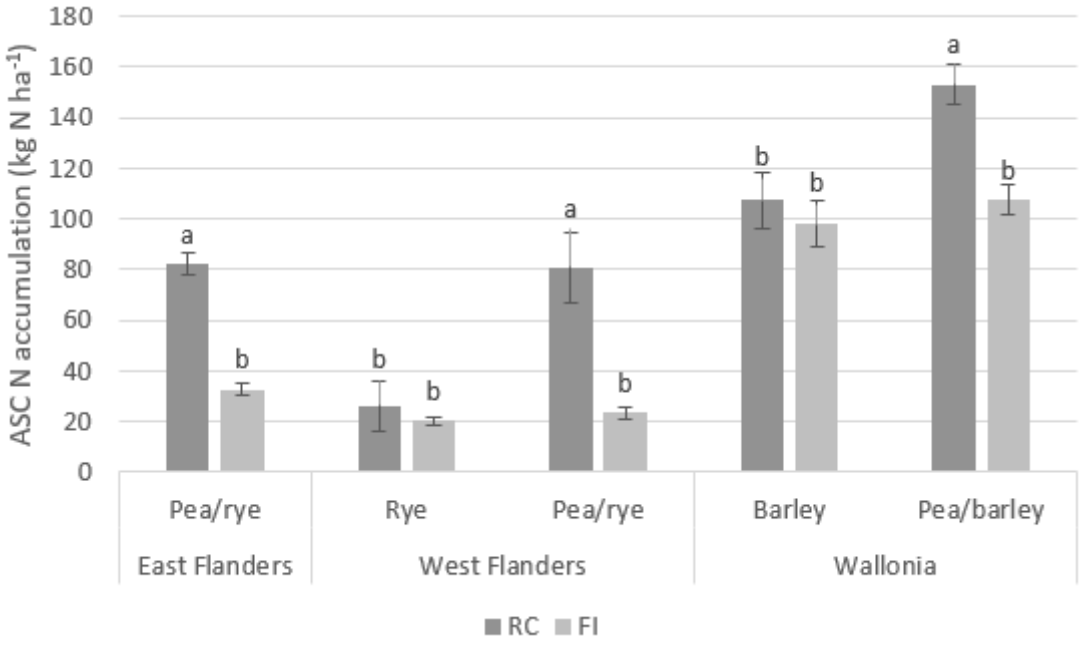

Disclosure of Interest: None Declared

Keywords: cover crop, soil mineral nitrogen, winter barley, winter pea, winter rye