IN ORGANIC CROP ROTATION WINTER COVER CROPS IMPROVE SOIL, WEED SUPPRESSION AND CROP YIELDS

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Abstract. *The aim of this study was to investigate the effects of different winter cover crops (CC) in combination with composted cattle manure on weed infestation, crop yields and soil characteristics. The experiment was conducted in 2012-2014 in three different organic cropping systems under five-field crop rotation (barley undersown with red clover, red clover, winter wheat, peas and potato). The control system followed the given rotation, whilst in the second and third organic system also winter cover crops (ryegrass after winter wheat (in 2012) and mixture of winter oilseed-rape and winter rye (since 2013); winter oilseed rape after pea and winter rye after potato) were used. In the third organic system composted cattle manure in addition to winter cover crops was applied. The results indicate, that winter cover crops reduced the dry biomass and density of weeds compared to the control system. In 2012 and 2013 the best suppressor of weeds was winter rye, in 2014 the mixture of winter rye and oilseed rape. In 2012 and 2013 there was a statistically significant increase of barley and potato yields under the combination of green manure with cattle manure. These results also indicate a remarkable improvement of soil properties, such as the decrease of soil acidity and increase of Carbon (C) content.*

Key words: *winter cover crop, weeds, carbon, soil pH, crop yield.*

INTRODUCTION

The first and capital principle of agronomy and thus the key for successful crop production begins with proper soil management by growing technologies [1]. However, in organic farming weeds are the main crop yield decreasing factors. In ecologically friendly cultivation weeds can be controlled by crop rotation, harrowing, inter-row tilling, mulching, growing legumes in rotation and cover crops [2],[3].
Winter cover crops drilled after the main crop harvest prevent nutrient leaching and improve other soil characteristics [4],[5] when incorporated into the soil [5].
Cover crops can improve agro-ecosystems in many ways: they provide soil cover and thus prevent water and wind erosion [6],[7], absorb, convert and redistribute nutrients, increase the soil organic matter content [8], ensure habitats for beneficial insects and suppress weeds by providing competition for water, light, nutrients and space or by releasing allelopathic chemicals from either living or decomposing plant tissue [9],[10]. Cover crops also avoid or reduce the soil-borne plant diseases [11]. In Estonian conditions the study of role of winter cover crops in crop rotation was started only few years ago. The aim of the study is to investigate the influence of different winter cover crops and their combination with composted cattle manure on soil properties (soil organic carbon content and pH), weeds and crop yields in three organic farming systems.

MATERIALS AND METHODS

Experimental site and design:

The five-field crop experiment with three different organic systems was started in 2008. The crops grown in succession were as follows: barley (*Hordeum vulgare L.*) undersown with red clover (*Trifolium pratense L.*), red clover, winter wheat (*Triticum aestivum L.*), peas (*Pisum sativum L.*), and potato (*Solanum tuberosum L.*). The control System (Org 0) followed this rotation. Winter cover crops were used as green manure in System Org I: ryegrass in 2012 and the mixture of oilseed rape and winter rye in 2013 after winter wheat, winter oilseed rape after peas and winter rye after potato. In System Org II winter cover crops were used as green manure and in spring composted cattle manure – 20 t ha^{-1} for potato, 10 t ha^{-1} for winter wheat and for barley was applied.

The experiment itself was established in four replications, each plot (60 m^2) situated in a systematic block design. The field is the property of the Department of Field Crop and Grassland Husbandry of the Estonian University of Life Sciences. The field's location is near Tartu (58°23´N, 26°44´E). The soil type was sandy loam Stagnic Luvisol according to the World Reference Base classification [12], the humus layer was 20-30 cm [13]. The ploughtable layer was 27-29 cm.

The cover crops were sown with the Kongskilde sowing machine right after the harvesting of the main crop and in the beginning of May they were ploughed into the soil. In cereals, potato and peas mechanical weed harrowing was used to control weeds. Red clover was cut twice: mid of June and during the second half of July and ploughed into the soil in all organic systems. Cereals and peas were harvested at the beginning of August, using a Sampo Rosenlew experimental harvester. Potato tubers were hand-collected in August-September. Yield data were adjusted to dry matter content.

Soil samples

Soil samples were collected once a year in April before any field operation, by taking eight samples per plot from 0 to 25 cm depth for making one average sample. Every sample was air-dried, ground and passed through a 2 mm sieve. An aqueous solution of soil was prepared in KCl 1M (1:2.5) for determining the pH, meanwhile the organic carbon concentration (Corg) was determined by the Tjurin method.

Weed samples

All data regarding the five-field crop experiment was collected according to TILMAN-ORG Handbook of Methods [14]. Total dry mass and density of weed species were measured in the end of April before the cover crops were ploughed into the soil and three weeks before harvesting the rotational crops. All measurements were carried out in four replications per each plot with a 25 x 25 cm frame. All weed specimens were collected and counted by species. Total biomass was weighted using only aboveground biomass after the weed samples were dried (80 °C) to a constant weight.

Weather conditions

The experimental field is situated 59 m above sea level and is a part of the South-Estonian upland agro-climatic region. The average annual sum of active air temperatures (daily average>5 °C) is 1750-1800 °C, mean annual temperature + 4.4 (+30…-30) °C with precipitation rates of 550-650 mm. The weather conditions in 2012 and in 2013 differed significantly – in 2012 the total precipitation during the growth period was 102 mm higher than usual, whereas in 2013 the summer was mostly hot and dry, compared to the long-term average values. In 2014 the spring was warm, but the beginning of summer was rainy and cold whereas in July the weather turned warm again.

Data analyses

Statistical analyses were performed by using the Statistica software package (version 11.0). Significant differences between cropping systems, winter cover crops and experimental year were tested by Fisher's least significant difference test. The statistical significance level was set at $p<0.05$.

RESULTS AND DISCUSSION

Soil carbon content and pH

Planting cover crops before the main crops can significantly improve physical, chemical and biological characteristics of the soil, thus leading to much improved soil health and thereby higher yield of the principal crops. The increase of C content provides more stable soil structure and this increases aeration, soil water holding and buffering capacities. Furthermore, sufficient organic matter content in the soil allows the release of available nutrients to plants [5],[16],[17]. Both winter cover crops (Org I) and winter cover crops with cattle manure (Org II) had tendencies to the accumulation of organic C with time (Fig 1) and thus reduced the acidity of the soil. The excessive soil acidity inhibits the availability of plant nutrients and thus the growth and development of plants is supressed, but with the decrease in acidity the nutrient availability recovers [16]. Compared to Control System (Org 0), there was a significant rise in soil pH in Systems Org I and II (Fig 2). The decrease of soil acidity in Systems Org I and II is mostly due to the increase of C content in the soil. The increase of C content and decrease of acidity indicates also, that cover crops improve soil physical, chemical, and biological properties, thus improving the productivity of subsequent crops [5], [16].

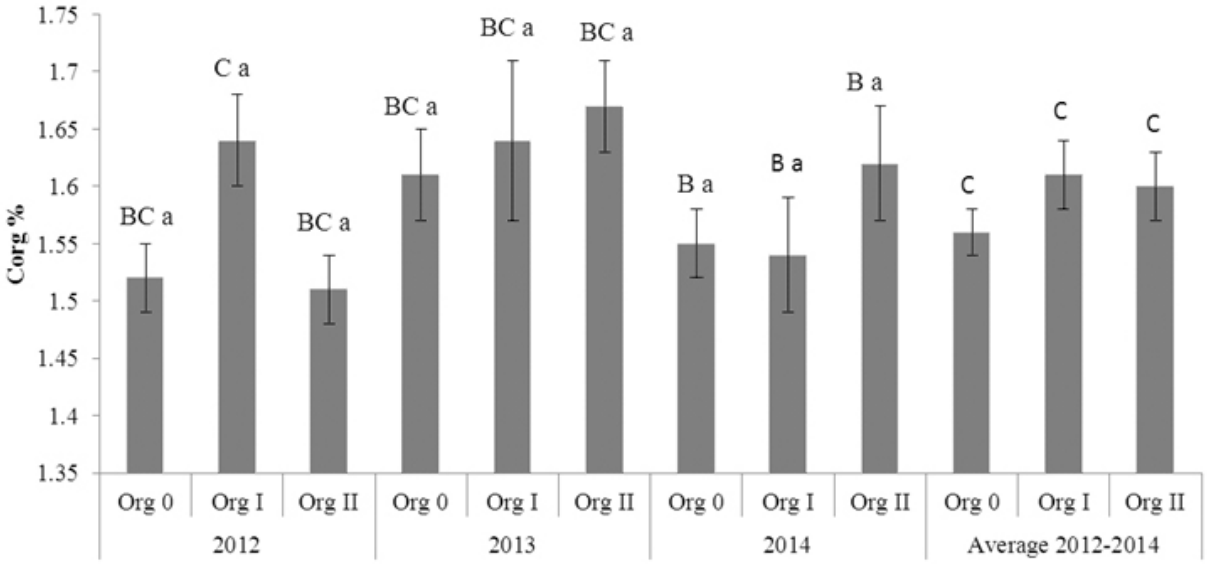

Figure 1. **Total C content (%) in the soil in spring in organic cropping systems in 2012-2014. (Org 0 – without CC, Org I – with CC; Org II – with CC and composted cattle manure). Means followed by a different capital letters indicate significant influence (Fisher's LSD; p < 0.05) of the system, small letters indicate significant influence (P < 0.05) of the year. ± value represents standard error of the mean (SE).**

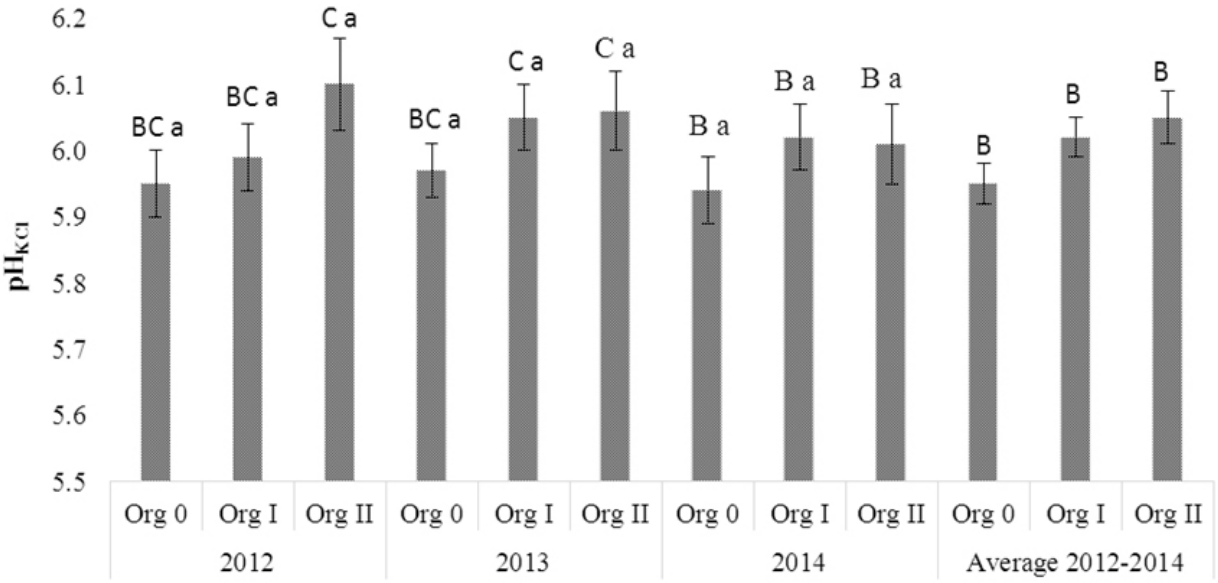

Figure 2. **Soil pH in spring in organic cropping systems in 2012-2014. (Org 0 – without CC, Org I – with CC; Org II – with CC and composted cattle manure). Means followed by a different capital letters indicate significant influence (Fisher's LSD; p < 0.05) of the system, small letters indicate significant influence (P < 0.05) of the year. ± value represents standard error of the mean (SE).**

Weed infestation before cover crop incorporation

Since cover crops control weeds in arable fields under organic farming conditions, the biomass and density of the weeds were influenced by the system, the cover crop species and the year. In 2012 the weed dry biomass was the highest in winter oilseed rape and lowest in winter rye (Fig 3). The weed density was also the lowest in winter rye (Fig 4). In autumn of 2012 mixture of winter rye and oilseed rape as green manure cover crop was used instead of ryegrass. Such replacement was made due to very small amount of ryegrass biomass, which did not supress weeds efficiently. This phenomena is significantly demonstrated by

measurements of weed density, which was highest in ryegrass (Fig 4). This finding is also confirmed by earlier research made regarding the ryegrass biomass production in Estonian conditions [15].
In 2013 the weed biomass was similar to previous year – the highest in winter oilseed rape and lowest in winter rye, with statistically significant results in System Org II (Fig 3). The weed density results were in accordance with the weed biomass with highest rate in winter oilseed rape and lowest in winter rye with also statistically significant results in System Org II (Fig 4). In 2014 the results somewhat differed from previous years – weed biomass was the highest in winter rye (Org I). The lowest biomass values were observed in the mixture of winter rye and oilseed rape (Fig 3). Weed density on the other hand was highest in winter oilseed rape and the lowest in the mixture of winter rye and oilseed rape (Fig 4), similarly to the biomass values.

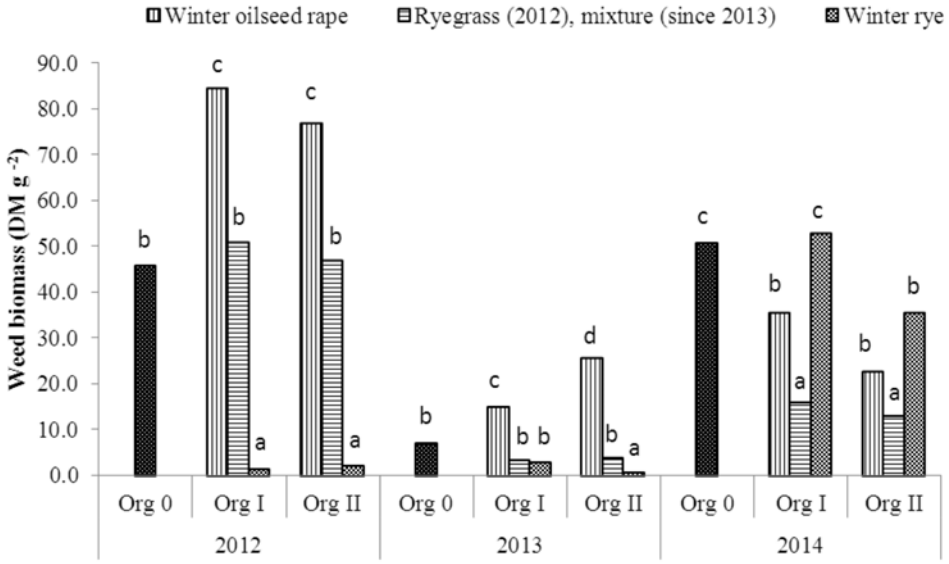

Figure 3. **Weed dry biomass (g m^{-2}) in green manures as winter cover crops (CC) before incorporation to soil in organic cropping systems in 2012-2014. (Org 0 – without CC, Org I – with CC; Org II – with CC and composted cattle manure). Different letters indicate significant influence ($p < 0.05$) of cropping systems in different years.**

These results indicate, that winter rye has very good weed suppressing ability compared to other winter cover crops. Furthermore, besides the lower biomass values in winter rye, the weed density was also lower than in other crops. As an exception 2014 could be pointed out, where weed biomass was highest in winter rye (Fig 3). This could be resulted from poor tilling of the rye in autumn.

Crop yields

Green manures had tendencies to increase yields in all rotation crops. Statistically significant increase of barley yield was reached in 2012 and 2013 in System Org II, but in 2014 no significant differences were found (Fig 5). As the 3year average, the yield significantly increased in Org II. A possible explanation for the yield increase may be associated with the effect of manure and cover crops. While in 2012 the yield of winter wheat increased significantly in System Org II, in 2013 and 2014 the tendency was stronger due to the effect of cover crops in Org I system. The lower yield level in last two years was caused by unfavourable weather conditions.
The yield of potato varied significantly between experimental years. In 2013 with drought conditions the effect of enhanced soil conditions on potato yield was observed, when potato yield increase significantly under systems Org I and Org II. The results also indicated that in organic rotations with winter cover crops high yield of peas for organic cultivation are achievable (depending on year and cropping system 1.6-2.9 DM t ha^{-1}) (Fig 5).
Our findings are consistent with those pointed out in [5], where there is claimed, that soil organic matter content contributes positively to soil fertility, crop yields and overall soil sustainability, which all are achievable by growing cover crops as green manure.

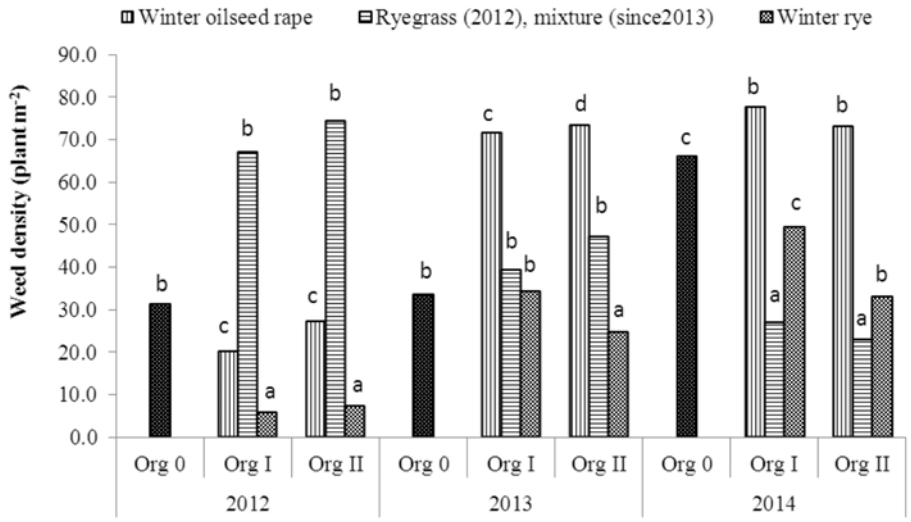

Figure 4. **Weed density (plant m^{-2}) in green manures as winter cover crops (CC) before incorporation to soil in organic cropping systems in 2012-2014. (Org 0 – without CC, Org I – with CC; Org II – with CC and composted cattle manure). Different letters indicate significant influence ($p < 0.05$) of cropping systems in different years.**

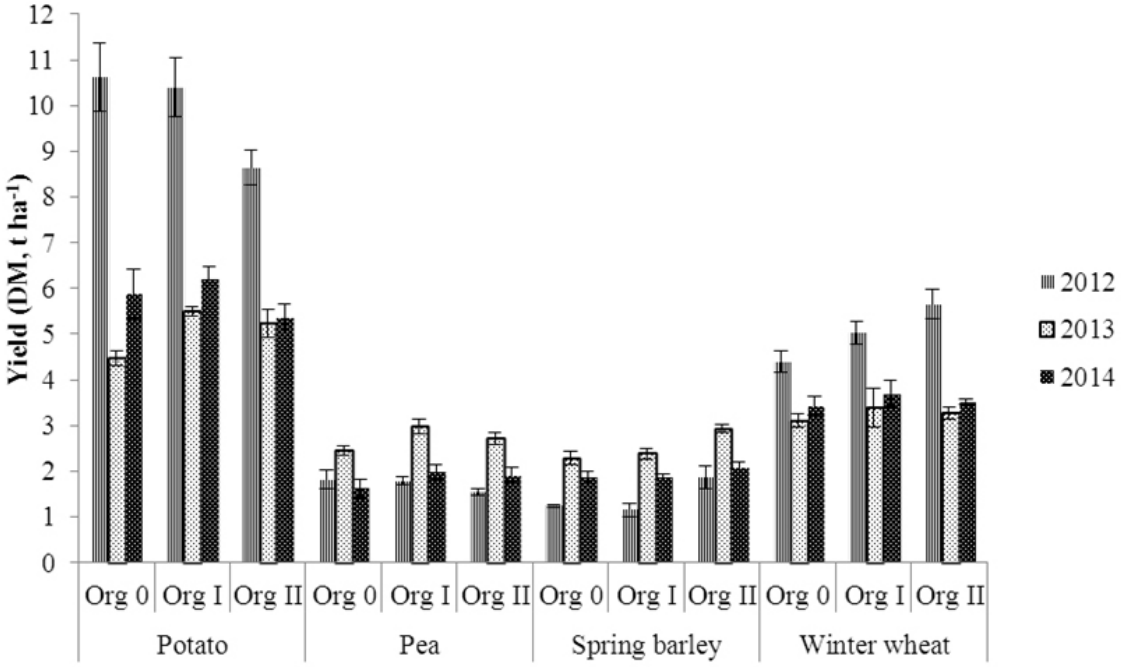

Figure 5. **Yield of rotation crops (DM, t ha^{-1}) in 2012-2014. (Org 0 – without CC, Org I – with CC; Org II – with CC and composted cattle manure). ± value represents standard error of the mean (SE).**

CONCLUSIONS

By addition of winter cover crops to the rotation, soil organic matter content can be increased, with or without manure application (systems Org I and Org II). Also the increase in soil fertility (C content) ensures the decrease in soil acidity in Org I and Org II systems. This study has shown that by growing winter cover crops as green manure weed infestation is reduced. Significant importance is on the species of the cover crop: as an average of experimental years the weediness before ploughing the cover crops into the soil was the lowest in variants where winter rye was used. As a result of improved soil fertility the yield of crops in the rotation has been increased. By incorporating the winter cover crops into crop rotation better conditions for higher yield and sustainable cultivation are established.

ACKNOWLEDGEMENTS

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