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FIRST RESULTS OF EXPERIMENTS FOR CARBON ENRICHMENT WITH DIFFERENT LAND USE TECHNIQUES UNDER ORGANIC AND CONVENTIONAL FARMING

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Abstract: Since agricultural soils are far from saturation (Vaccari et al.2011), there is a potential of carbon (C) sequestration with land use change. At the Thuenen-Institute of Organic Farming in Germany several stationary field experiments were established to increase soil organic carbon (SOC) content with different land use techniques. On the sites no differences in initial SOC and total nitrogen (N_{tot}) contents of soils, before implementation of the trials were detected. In the first year significant lower yield and also chlorophyll contents were found in organic spring wheat on plots without ploughing. Compared to the use of wood-chips and seed treatment with N-binding bacteria organic manures improved the yields. Undersown crops in organic faba beans and conventional rapeseed caused no significant yield effects.

Introduction: Because of the high amounts of carbondioxide (CO_2) in the atmosphere and the function of soils as a sink for C, the possible sequestration of C into the soil is of higher interest. Farmers could preserve and also increase organic C in soils (SOC) with alternative land use (Lal 2010). However, it is still unclear how farmers could efficiently increase C contents in their soils. The specific objectives of this study are to investigate short term effects in C dynamics under different land use, namely i) with undersown crop (also in conventional farming) ii) with and without ploughing and iii) with organic manure in organic agriculture. In the following we describe initial SOC contents and the effects of different treatments on biomass yields in the first project year.

Material and methods:

Site and experiment description

The experiment sites are located at the Thuenen-Institute of Organic Farming, and an adjacent site under conventional farming. Mineral nitrogen content in the topsoil in spring in period from 2007 to 2012 ranged from 14 to 28 kg N ha^{-1}. SOC in these years varied between 1.01% and 1.26% and total N (N_{tot}) between 0.11% and 0.12%. The pH of the soil was between 6.2 and 6.6. The cultivated main crops were oat, clover-grass and spring barley. In 2018 summer wheat with a manure application 60 kg ha^{-1} N had a grain yield of 3.1 Mg ha^{-1}. The crop at the conventional site was winter barley with a yield level of 9 Mg ha^{-1}.

Four separate stationary trials were established. Trial 1 and 2 'Undersown crops' consisted of three variants on an organic (1) and conventional site (2) each: control (no undersown crop), undersown crop removed and undersown crop incorporated. Two further trials one with and without ploughing (Trial 3 'Soil cultivation'), and one with and without various 'Organic manures' (Trial 4) were established at the organic site. Each trial consists of four randomised replicates with a plot size of 15 m length and six meters width. Results were analysed by ANOVA and post hoc tests. Main crops in 2019 in trial 1 and 2 were field bean (*Vicia faba*) and rapeseed (*Brassica napus*), respectively. As undersown crop for field bean a mixture of German ryegrass (*Lolium perenne*) and red clover (*Trifolium pratense*) was chosen. Under rapeseed Italian ryegrass (*Lolium multiflorum*) was added to this mixture. The variants in ploughing additionally differ in the intensity of soil tillage. In the trial 3 biogas digestate, mushroom substrate, woodchips and injection of seeds with N-bacteria were utilized.

Soil sampling and analysis

Soil samples for C and N analysis were taken with sample rings of 100 cm^3 on each plot with five replicates in 5-10 cm soil layer, were mixed and used as representative sample for the top-soil layer (30 cm). Samples were dried at 40°C and sieved for 2 mm. The rock fragments of the samples were removed and weighed. The equations from Poeplau et al. (2017) were used to determine soil bulk density, soil organic carbon (SOC) and N_{tot} stocks, respectively. Density of rock fragments were approximated by 2.6 g cm^{-3} as given by Don et al. (2007). The samples were ground with a pestle. N_{tot} and total C were determined after dry combustion (elemental analysis, DIN ISO 10694 (1996)). Since the soils did not indicate any carbonate contents after addition of hydrochloric acids, total C equals SOC content.

Results:

Chlorophyll contents

Chlorophyll contents in wheat plants measured with SPAD meter showed significant differences ($p<0.05$) in plots with and without ploughing. Plants in plots that were not ploughed had the lowest chlorophyll content. In trial 4 highest values occurred in plots with mushroom compost and biogas digestate. The plants in the variant with woodchip had the lowest chlorophyll content. These differences could not be statistical secured.

Biomass yield of undersown crop

Eight weeks after harvest of the main crop in all plots with and without undersown crop on the organic field were covered with weeds. Biomass dry matter yield of the undersown crops "removed" ,"incorporated" and the weeds in "control" amounted on average 0.83, 0.75 and 0.85 Mg ha^{-1}, respectively (not significant) (Table 1). Variants with undersown crops in rapeseed on the conventional field had on average 2.10 and 1.76 Mg ha^{-1} dry matter biomass yield, respectively. The plots without undersown crop were covered with volunteer rapeseed (1.02 Mg ha^{-1} biomass). The differences of biomass yields between volunteer rapeseed and undersown grass were significant ($p<0.05$).

Crop yields

Grain and straw yield of field bean on the organic field site without undersown crop were 4.13 and 3.60 Mg ha^{-1}, respectively. This was higher than the corresponding variants with undersown crop, but not significant. Also in the conventional trial with rapeseed there were no significant yield differences found.

In organic summer wheat at a very low overall yield level the grain and straw yield with "no ploughing" were 0.67 and 1.49 Mg ha^{-1}, respectively and significantly lower ($p<0.05$) than the corresponding variants.

In the trial with organic fertilizers summer wheat yields differed significantly. Here the variants with wood chips and seed treatment with N-binding bacteria had lower crop yields than the variants with mushroom and biogas digestate and the control ($p<0.05$).

Soil initial N_{tot} and SOC contents

The initial N_{tot} and SOC contents of the soil before the start of experiment in the organic field ranged from 0.12% to 0.18% and from 1.13% to 1.62%, respectively. On the conventional site the concentrations were between 0.13-0.16% and 1.21-1.57%, respectively (Table 1). The initial concentrations and also the calculated stocks were not significantly different in the trial.

Experiment variants	N [%]	C [%]	N stock [Mg ha^{-1}]	C stock [Mg ha^{-1}]	Grain yield [Mg ha^{-1}]	Straw yield [Mg ha^{-1}]	UC biomass [Mg ha^{-1}] for CF1 and CF2/N-tester for CF3 and CF4
CF1 without undersown crop	0.12	1.13	5.22	47.95	4.13	3.60	0.85
CF1 UC-removed	0.12	1.14	4.79	44.41	3.79	3.30	0.83
CF1 UC-incorporated	0.13	1.24	4.96	48.23	3.26	2.90	0.75
CF2 (conv.) without UC	0.16	1.57	5.72	56.15	4.07	8.57	1,02 B
CF2 (conv.) UC-removed					4.26	8.04	2,10 A
CF2 (conv.) UC-incorporated	0.13	1.21	5.16	48.04	4.22	7.98	1,76 A
CF3 without ploughing	0.14	1.28	6.19	57.51	0.67 B	1.49	29,2 b
CF3 ploughing	0.15	1.34	6.18	56.92	0.98 A	2.22	32.5 a
CF3 intensive soil working	0.14	1.27	6.02	55.59	1.03 A	2.17	33.1 a
CF4 without organic fertilizer	0.17	1.52	7.09	65.43	1.05 ab	2.27 ABC	34.3
CF4 mushroom compost	0.17	1.56	7.60	69.88	1.17 a	2.45 AB	36.7
CF4 biogas digestate	0.16	1.47	6.51	60.63	1.22 a	2.69 A	36.4
CF4 wood chips	0.18	1.62	7.49	67.45	0.83 b	1.87 C	32.8
CF4 N-bacteria injection	0.17	1.57	7.23	65.88	0.89 b	2.02 BC	34.1

Discussion: Differences by soil cultivation in organic spring wheat probably was due to the unfavourable root penetration conditions and nutrient availability in the variant without ploughing. As expected also manuring with biogas digestate and mushroom substrate increased plant nutrient availability, which was partly visible in chlorophyll contents of the plants and in higher grain and straw yields. These results are in accordance with Wasayaa et al. (2017), who also reported about the effects of different nitrogen levels and tillage systems.

Although the biomass dry matter of the volunteer crops in the control was higher than the yield of undersown crop, yield effects could not be secured in faba beans. A meta-analysis of Valkama et al. (2015) showed that undersown catch crops can reduce the grain yields up to 6%. However, the missing of clear effects might be explained by the fact that the biomass development of undersown crops mainly occurred after crop harvest, especially in rapeseed.

Since the initial N- and C-stocks of the investigated plots within the trials were not different, the measured differences of chlorophyll contents and yields are likely to be induced through the different management. The further investigations will analyse the effects of reduced tillage, incorporation of undersown crop or fertilization with organic manure on SOC and yields on the elaborated sites.

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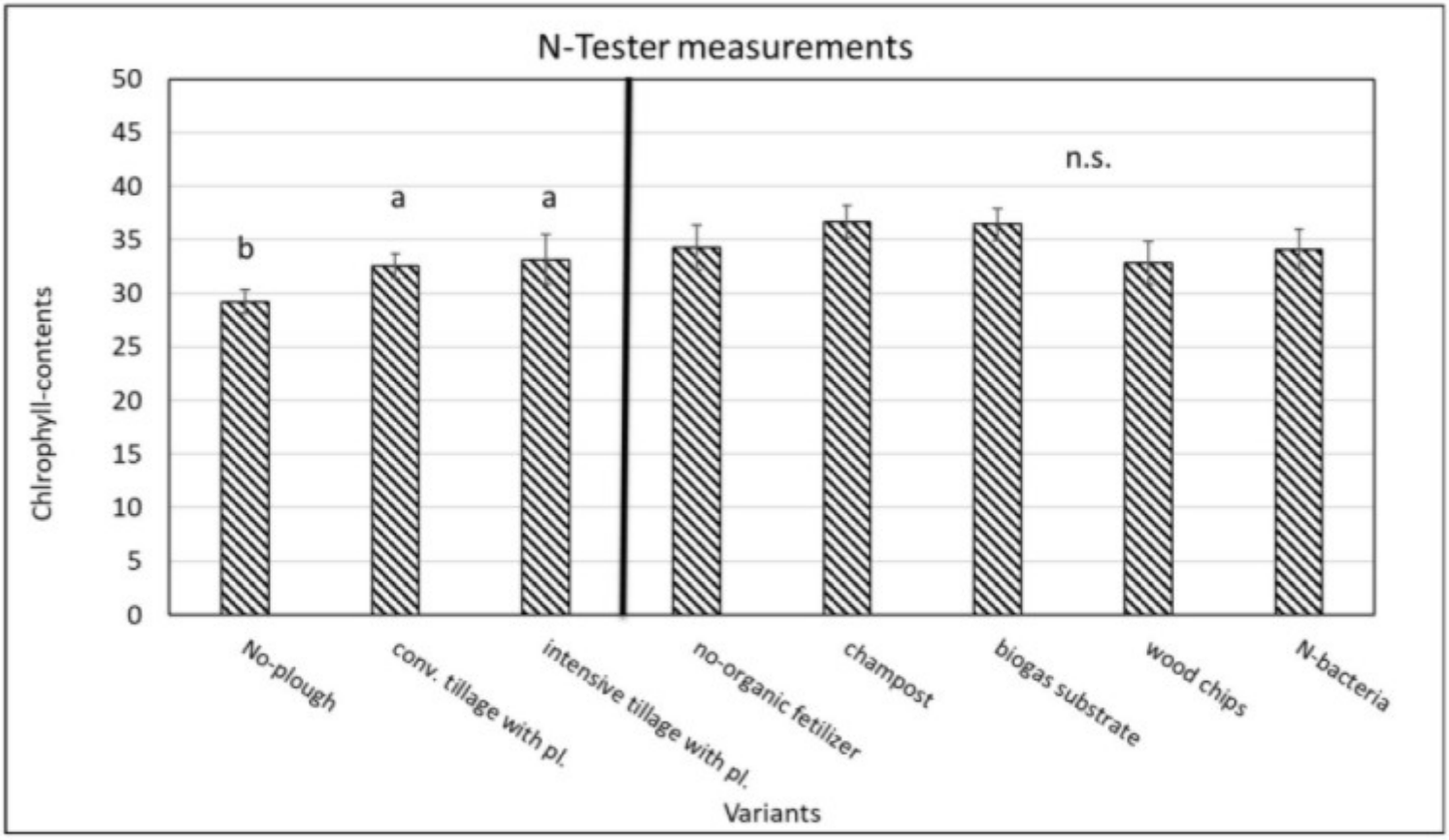
Image:



Disclosure of Interest: None Declared

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