Hungary study site experiment 1: ORGANIC VERSUS INORGANIC NITROGEN FERTILISATION FOR INCREASING SOIL ORGANIC CARBON CONTENT

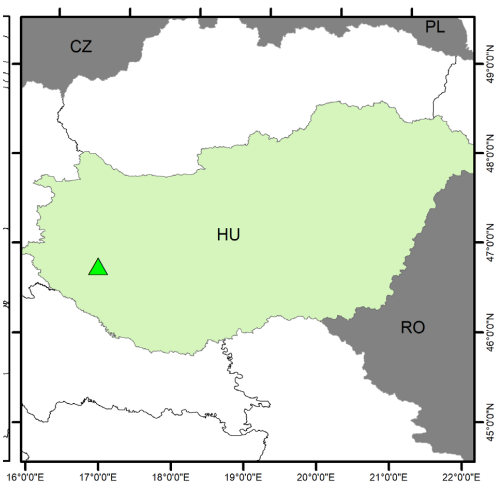
The problem

Soil organic carbon loss can result in crop yield losses over time as it limits the ability of the soil to provide plants with the nutrients and good soil structure they rely on.

The main objective of this experiment was to evaluate the effect of mineral and organic fertilization on soil organic carbon content as well as on grain production of cereals. This is part of a longer-term experiment established in 1983. The treatments involve increasing the rate of mineral N fertilization and the complementary application of the organic fertilizers in a three year crop rotation (consisting of maize, winter wheat and winter barley).

The proposed solution

This experiment was conducted on an experimental field managed collaboratively by researchers and farmers. The field is located in Keszthely, Western Hungary at an altitude of 118m, covering an area of around 10000 m2. The topsoil here is primarily classed as sandy loam.



Experimental design

Treatment no.	Mineral N fertilisation	Organic fertilisers
1	N0	None
2	N0	Farmyard manure
3	N0	Green manure
4	N3	None
5	N3	Farmyard manure
6	N3	Green manure

The mineral N fertilizer rates were 0 and 210 kg/ha N for maize, 0 and 150 kg/ha N for winter wheat, and 0 and 120 kg/ha N for winter barley in the N0 and N3 abbreviation respectively. It was applied in the form of solid Calcium Ammonium Nitrate.

Measurements taken: Saturated hydraulic conductivity, water stable aggregates, bulk density, mineral N, available P, SOC, pH, earthworms, crop yield, microbial biomass carbon, cation exchange capacity.

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Results

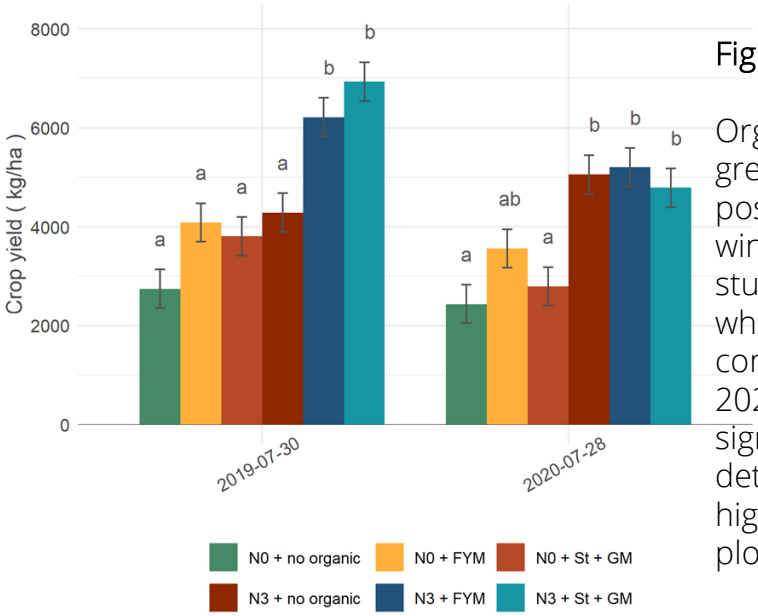

Figure 1. Impacts of treatments on crop yield.

Organic amendments (FYM, straw/residue or green manures) influenced yield values positively even when FYM was applied to winter wheat during the second year of the study. The yield increase was significant when organic amendments were applied in combination with mineral N fertilizer. In 2020, when winter barley was grown, no significant effect of organic amendments was detected - only FYM applications resulted in higher (non-significant) yields on the N0 plots.

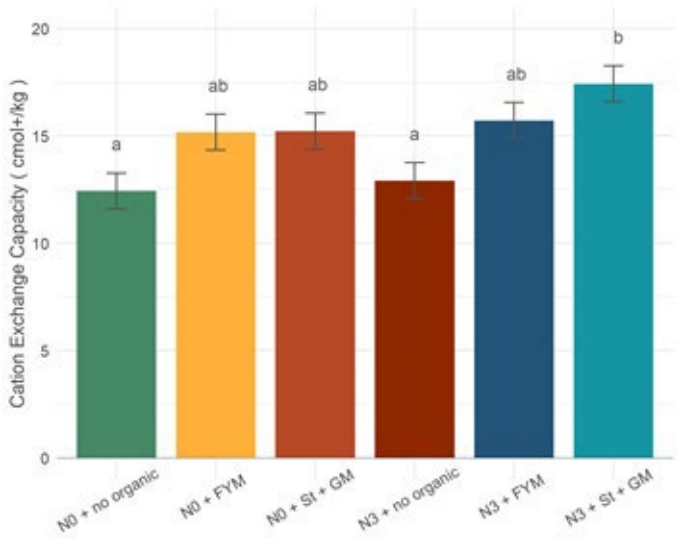

Figure 2. Impact of treatment on cation exchange capacity.

Cation exchange capacity is an important soil characteristic providing nutrient holding, retention and buffering capacity of the soil, influencing soil structure stability. Where organic amendments were applied, CEC values increased in both plot types. This increase was significant where green manure was applied in combination with mineral N fertilization (N3+St+GM) compared to the "no organic" variants.

Impact of treatments on soil bulk density

Bulk density was significantly lowered as a result of organic amendments. This suggests that these amendments can alter bulk density, leading to higher porosity, consequently better infiltration and aeration of the soil. In addition, lower bulk densities result in reduced soil compaction, suggesting that root development may also be improved by applying these amendments (FYM, straw/residue and green manures).

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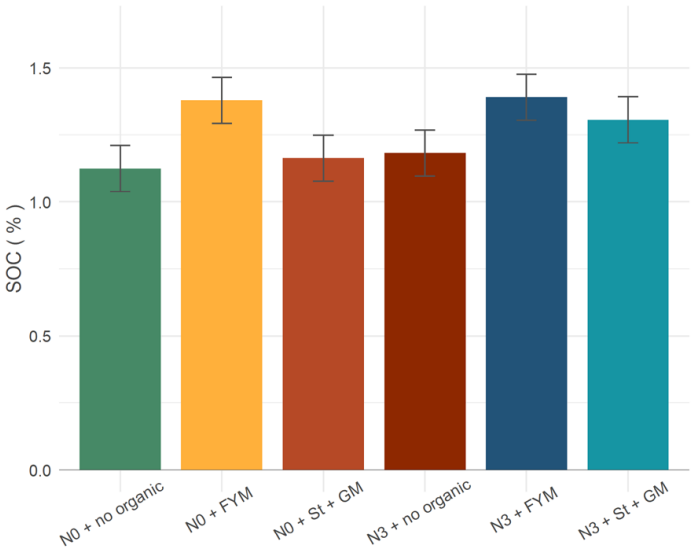

Figure 3. FYM increased SOC but not statistically significant as an effect of long-term application (since 1983) both in the case of N0 or N3 variants. St+GM amendment resulted in moderate SOM increase, only when the N3 rate was applied, presumably due to the larger amount of crop biomass produced in the N fertilized variant. SOM increasing effect of FYM was higher than that of St+GM.

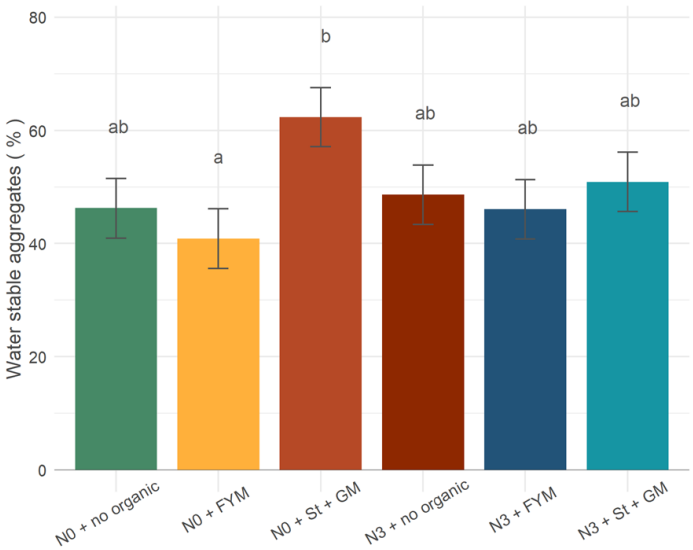

Figure 4. St+GM addition resulted in significantly higher WSA values compared to FYM application. WSA results are consistent with SOM results, since not SOC is responsible for soil structural stability itself, but other forces and effects (eg. microbiological processes and their beneficial effect during straw decomposition) play a role also.

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Economic findings

The costs of straw harvesting, manipulation and transport, as well as FYM spreading were not compensated totally by the higher income (benefits) of the resulting higher yield. On the other hand, under the control treatment (i.e., no organic amendment applications), extra income can be generated by selling the resulting straw. This can compensate towards the cost of straw harvest, manipulation and transport.

There were no significant differences between treatments and economic outcomes.

	AMT control	AMT SICS
Agricultural management technique	Straw is harvested and sold	FYM applied in each 3rd year
Investment costs	0	0
Maintenance costs	25	31
Production costs	89,6	109,2
Benefits	1194,2	1079
Summary = benefits - costs	1080	939
Percentage change	15%	

AMT means agricultural management practice

Socio-cultural dimension

Socio-cultural analysis revealed that straw incorporation led to the most positive outcomes in terms of organic amendments. The main reason for this is despite the yield increasing effect of FYM, this is compensated by the higher benefit (income) value of selling straw in no organic control plots as well as the lower costs of residue management on St plots.

FYM application can have several positive effects on soil properties but can also promote weed infestation and increase soil compaction during spreading.

Better soil quality and lower use of external inputs resulted in farmers feeling as though their reputations had improved.

Stakeholder feedback

- Stakeholders stated that the results of this experiment were plausible but reiterated the importance of maximising profitability and financial sustainability
- The difficulties in obtaining organic manures was referred to by farmers who do not have livestock within their farming systems. Alternative ways of procuring manures (both FYM and green) need to be considered.
- Benefits of the SoilCare project appear to be that it has helped stakeholders recognise the benefits of non-inversion tillage, cover crop production and mulching with straw for managing pests and conserving soil and its biodiversity. Some farmers are now considering making changes to their farming systems as a result.

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Key findings

Both variants of organic amendment resulted in positive influences on soil properties as well as on productivity. Less risk for soil degradation (compaction induced by traffic while spreading) and weed infestation as well as higher economic sustainability occurred, when Straw was left on-field and recycled back into the soil.

Overall, sustainability was highest when straw was left on the field. FYM application also resulted in good sustainability regarding biophysical parameters, but economically it was the least effective comparing to the no organic (control) and St variants. This statement is correct when the market price of straw is high. As soon as the price of straw decreases, another economic evaluation of using FYM will be necessary.

FYM led to the highest increases in SOM. This can be explained by better availability of fresh straw - as a labile form of organic C - for decomposition processes, than a more stable form of organic substances after a fermentation process during maturation of FYM (Hannula et al. 2021).

Conclusions

Organic amendments generally increased yields even in combination with mineral N fertilizer. In addition, several soil properties were improved as a result. FYM led to significant increases in SOC, whilst St and GM led to increased water stable aggregates.

Both amendments increased CEC and decreased BD values, providing higher nutrient holding and buffering capacity, increasing soil structure stability, as well as better infiltration and aeration of the soil, enhancing better root growth. These amendments are by-products of farming. FYM is produced in mixed farms dealing with crop production and animal husbandry as well. Extra costs of production and value of FYM are compensated by the incomes of animal husbandry. The extra expenditures – as high as 140 EUR/ha - occurs by harvesting straw and loading spreaders and broadcasting on the field are recovered by the extra yield in the next 2 years, and other extra benefits can be detected in soil properties. When FYM application is compared to St addition, both economic efficiency and environmental impact is better in the case of St recycling.

Fact sheet authors

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