German study site experiment: EFFECT OF GLYPHOSATE AND COVER CROPPING INTERACTION WITH SOIL ORGANISMS

The problem

The use of glyphosate is highly debated, with many stakeholders pushing for prohibition of its use. This conflict illustrates a common structural problem of farming in industrialised countries, requiring research projects and stakeholder panels to avoid polarisation and destructive dynamics.

Conventional conservation agriculture systems depend on herbicide use for weed control (seedbed preparation), thus it is important to understand the effects of glyphosate on soil organisms. It is also important to develop alternative management practices to ensure farmers can control weeds if a glyphosate ban is eventually introduced.

The proposed solution

The German Study Site at the Tachenhausen research farm has investigated the effects of glyphosate on soil microorganisms in a soil-conservative cropping system. Reduced tillage was tested to determine whether it could reduce soil erosion and soil fertility loss. The use of cover crops may also enhance this effect and could additionally have a potential for weed suppression. Cover crops may, therefore, help to avoid glyphosate under no-till systems.

Experimental design

Treatment no.	Cover crops (CC)	Glyphosate (GLY)
1	+	+
2	+	-
3	- (bare fallow)	+
4	- (bare fallow)	- (hand weeding)

3	4	2	1
2	4	1	3
4	2	2	1
1	3	4	3

Over two seasons, all four treatments were replicated four times on 24 m² plots.

The experiment started with a cover crops mixture over winter. Glyphosate was used on corresponding treatments for seedbed preparation two weeks before seeding. On April 25th 2019, the maize variety "Figaro" was sown on every plot, with a density of 9.5 plants/m². Harvested in autumn, it was followed by spring barley "Avalon" sown in March 2020 with 450 seeds/m². Reduced tillage, fertilizer and pest management were identical across all plots.

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Analysis was conducted according to the SoilCare monitoring plan. This plan was extended to include soil microbiological analysis methods.

Measurement	Time of year	Approach used
Earthworm abundance	spring 2019 and early summer 2020	Hand sorting of soil excavation
Arthropod abundance	spring 2019	pitfall-traps in the field
Microbial biomass carbon and nitrogen	spring 2019 and 2020	Chloroform-fumigation-extraction of soil samples
Potential enzyme activities: ß-Glucosidase Xylanase N-Acetyl-glucosaminidase Phosphatase	spring 2019 and 2020	Multi-substrate-assay of soil samples

Results

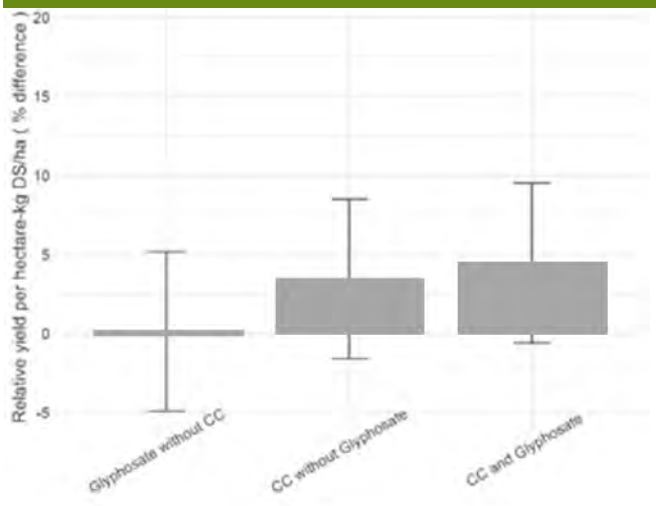

Figure 1. With cover crops (CC), a slight trend for higher yields was observed in comparison to the control treatment 4 (set at 100 %). The application of glyphosate had no significant effect on the crop yield, quantity and quality, in both years.

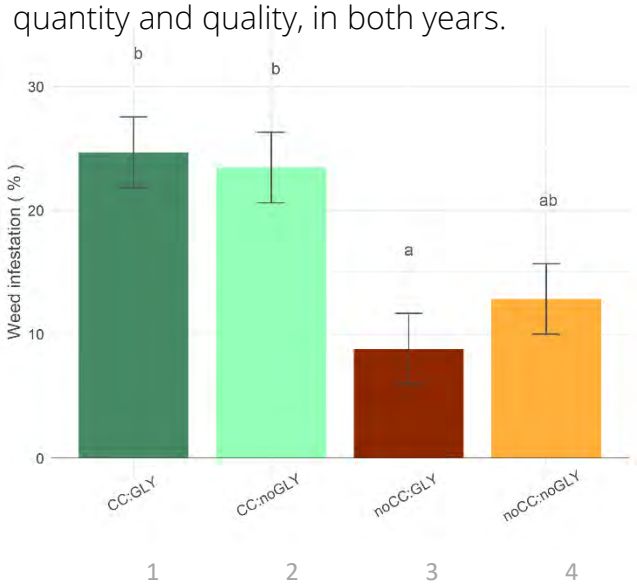

Figure 2. In June 2019, during maize growth, weed infestation (soil cover by weeds) was significantly higher in the cover crop treatments (CC=cover crops; GLY= glyphosate). There was no glyphosate effect. With higher weed infestation, overall soil covering was correspondingly higher: Treatments 1 and 2 had on average 30 % soil covered.

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Further results

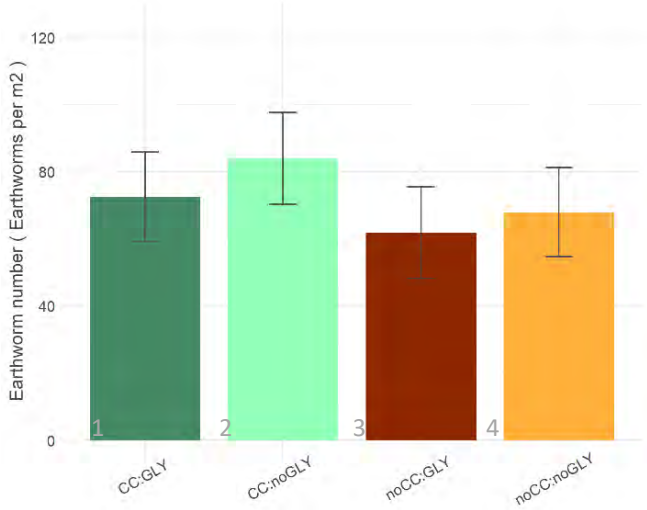

Figure 3. The results of 4 sampling dates showed no effect of glyphosate on earthworm abundance. A slight trend was observed for earthworms being more abundant with more C input through cover crops. The biomass of the earthworms (g/m²) was significantly higher in both cover crop treatments than in the fallow treatments (Marc Thomas, data not shown).

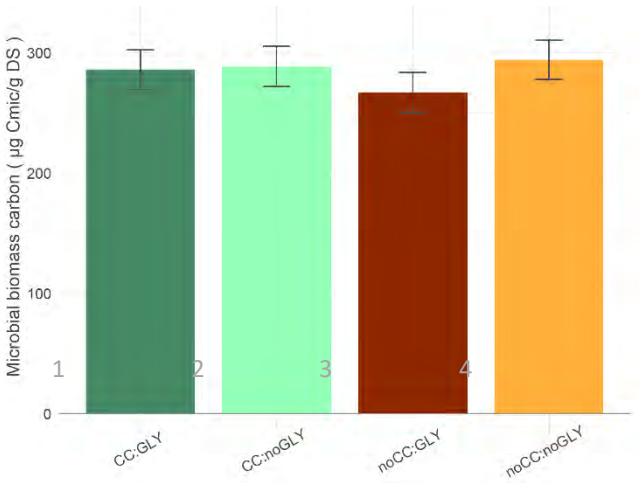

Figure 4. There was no significant effect of treatments on soil microbial biomass carbon nor on measured enzyme activities (data not shown).

In a previous experiment with the same treatments, abundance and biodiversity of soil microorganisms were enhanced by cover crops, but they were not influenced by glyphosate (Adrian Langarica Fuentes, data not shown).

After the application of glyphosate, there was a temporary stress response of microorganisms, indicated by an increase in ß-glucosidase activity. This reaction was stronger in the treatments without cover crops than with (Fig. 5).

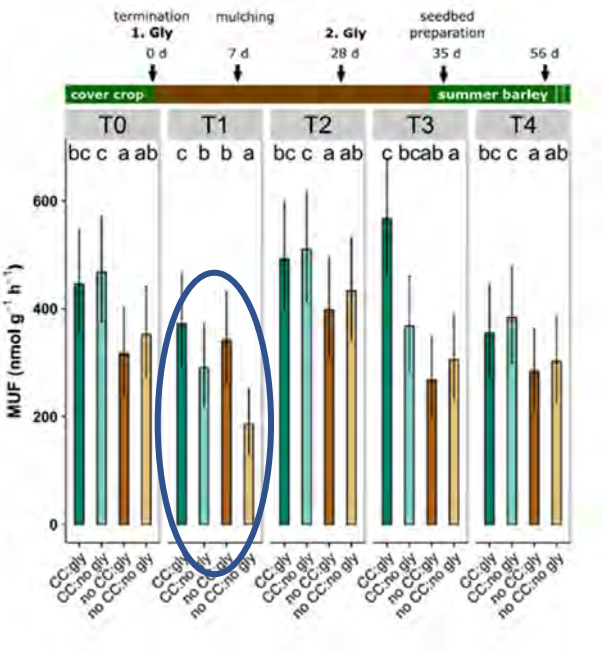

Figure 5. Modelled means of β-glucosidase activity in response to the treatments (CC=cover crops; gly= glyphosate) over time: T0-T4 (0, 7, 28, 35 and 56 days after 1st glyphosate application). Error bars indicate 95% CI. Means with the same letter(s) are not significantly different ($p < 0.05$, Tukey) (Sehrish Abdullah).

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Stakeholder findings

- In general, farmers saw the results as aligned with their understanding of cover cropping.
- However, some parts of the results were unclear, with one stakeholder questioning why weed infestation was higher with cover crops than without despite cover crops being known to supress weeds. This was not a major concern as yields were unaffected despite the higher weed burdens.
- Farmers were keen to have conclusions drawn which are relevant on a regional basis as the local climate may have affected the results.
- A key limitation recognised by farmers was the short-term nature of the study as certain aspects of land management would not have responded in the time-frame of this project.
- There was a consensus that further research into conservation agriculture without glyphosate is needed.
- It was agreed that the SoilCare project has been beneficial for connecting stakeholders and raising awareness of SICS.

Factors encouraging the adoption of cover crops:

- Reduced need for fertilisers
- Biodiversity enhancement

Barriers preventing the adoption of cover crops:

- Insufficient knowledge of farmers
- Cost of seeds
- Crop rotation management is complicated (i.e. establishment and timing of tillage must be precisely matched)

Factors encouraging the adoption of reduced tillage:

- Reduced fuel consumption, reduced workload
- Heavy soils can be cultivated
- Decreased erosion
- Societal demand for sustainable products
- Field demonstrations

Barriers preventing the adoption of reduced tillage:

- Possibly lower yields
- Increased need for pesticides/new machines
- Crop rotation management is complicated
- Application of practice on stony soils“
- It looks wild”; pest management not possible without chemical plant protection
- Impact of market forces, particularly on glyphosate debate
- Promotion of organic farming with derogations from the ploughing ban

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Key findings

- The main crops showed no difference between the treatments, neither in yield quantity nor quality.
- Weed infestation and soil cover in the main crop in spring were higher with cover crops. There was no effect of glyphosate.
- The biodiversity and abundance of soil organisms depend on the input, quantity and quality of a carbon source.
- Earthworms benefit from a cover crops mixture from the first cultivation onwards.
- Glyphosate application tended to increase beta-glucosidase activity, this indicating temporary stress in microorganisms. No effects were found on earthworms.
- For maximum erosion control, direct seeding systems are best, however managing this without glyphosate is hardly possible.

Conclusions

- Soil organisms are an indicator for soil health and resilience.
- The aim of the field trial was to see if soil organisms were affected by glyphosate in a soil conservation tillage system.
- Cover crops play an important role and may be the key factor for suppressing harmful weeds, reducing the need for glyphosate, protection of soil against erosion and surface runoff and aiding soil organisms.
- As long as yields are not affected by increased weed populations, conservation tillage can be recommended. In cases where weed infestation exceeds the economic threshold, additional herbicides need to be applied or soil tillage needs to be intensified.
- Where glyphosate is replaced by an increase in tillage for weed control, the positive effects of conservation agriculture, in particular regarding earthworm abundance and erosion control, will be reduced.
- Conservation agriculture of the future needs to be developed without glyphosate. This will require shallow tillage and enhanced crop rotations, including cover crops and perennial grasses, to enable stable yields as well as to protect the soils and its organisms.

Fact sheet authors

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