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Impact of the Nutrient Relay Principle in Multi-Cropping Systems on Soil Structural Properties

Lina Juodytė, Rokas Jonaitis, Austėja Švereikaitė, Jovita Balandaitė, Dovydas Miliauskas, Kęstutis Romaneckas. Vytautas Magnus University Agriculture Academy, Department of Agroecosystems and Soil Science, Bioeconomy Research Institute

INTRODUCTION & AIM

Intensive agricultural practices increase the risk of soil erosion and compaction and contribute to the depletion of soil organic carbon and al nutrients (Liu et al., 2010). Numerous research is done regarding different aspects of multiple cropping, allelopathy, anthagonism or interactions between crops (Ries E.L. (1986); Bedoussac and Justes (2010); Ripoche et al. (2010); Soltys D. et al. (2013); Bogužas et al., 2018; Velička et al. (2012); Romaneckas et al. (2019); Sinkevičienė et al. (2024); Nishioka et al. (2022); Marcinkevičienė et al. (2024); etc. There is a growing need to develop sustainable agricultural practices that enable the cultivation of crops and minimizing harm to natural resources (Huss et al., 2022). Innovative governance and technologies are needed to sustainably increase agricultural production (Kremsa, 2021). Balandaitė et al. (2024) noted that multi-cropping is becoming an increasingly popular technique in agriculture to tackle major and complex agroecosystem problems such as biodiversity and soil fertility loss, erosion and degradation etc. Hauggaard-Nielsen et al. (2005) pointed out that interactions between crops and competition between species promote crop rooting, and the cultivation of multi-crops has a positive effect on the stability of the soil structure. Current investigation focused on nutrient relay at multiple cropping at zero mineral nutrition and its effect on soil structurality and stability, crop development, sustainability of the agroecosystems and the environment and bioeconomical efficiency.

We hypothesized that cereals with intercrops would inherit favorable growth conditions due to relay of nutrients and allelopathic substances and will support soil fertility and health, ensure the sustainability of agrocenosis and bioeconomic and energy efficiency.

METHODS

The field experiments at three vegetative seasons is planned to do twice at the Experimental Station of Vytautas Magnus University Agriculture Academy, Lithuania. The experimental site is located at 54°53′7.5″ N latitude and 23°50′18.11″ E longitude. The soil is Endocalcaric Amphistagnic Luvisol (*IDg4-k)*. The soil has a pH HCl ranging from 7.3 to 7.8, a total nitrogen content – 0.08–0.13%, and a humus content – 1.5–1.7%, available phosphorus – 189–280 mg kg^{-1}; available potassium – 97–118 mg kg^{-1}; available sulphur – 1.2–2.6 mg kg^{-1}; and magnesium – 436–790 mg kg^{-1}. Investigation aims to determine the effect of multicropping at minimal tillage intensity and zero inputs onto soil and environment. Rotation of faba bean, winter wheat, spring barley and maize is applied (Fig. 1) and nutrient relay efficiency is to be evaluated. Soil physical properties were assessed at two multicropping systems before and after establishing the systems: winter wheat with spring/autumn intercrops and spring barley intercropped into leguminous the subsequent season.

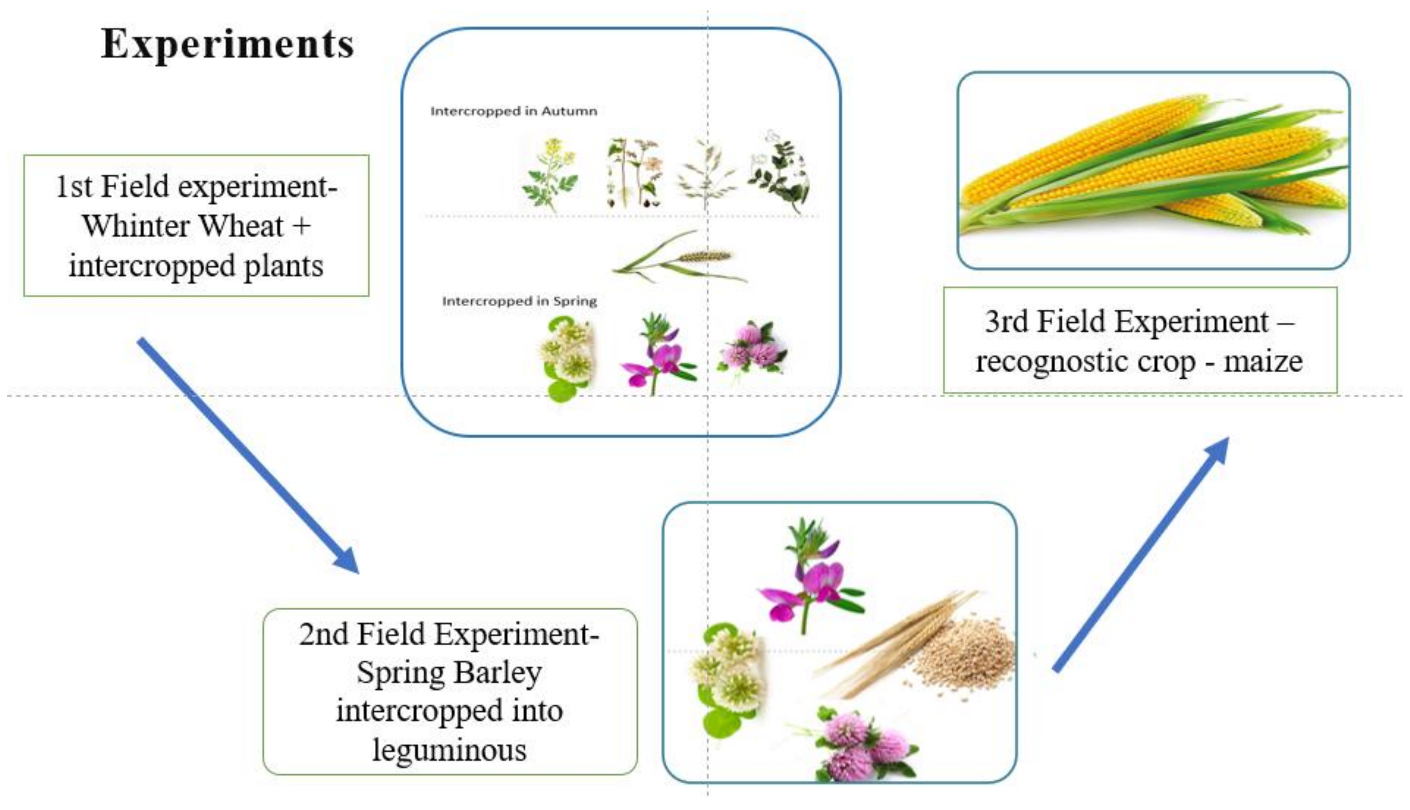

Fig. 1. Experiment plan for full rotation

Productivity and development indices, photosynthetic radiation, biomass and root DM, emissions and other data were gathered during vegetative seasons (Fig. 2 and Fig.3) (data not presented here).

Fig. 2. Four treatments, visual in October, 2024. *C/SB- Control/ Spring Barley, SB+RC- Spring Barley +Red Clover, SB+WC- Spring Barley +White clover, SB+V – Spring Barley +Vetch*

FUTURE WORK

Multicropping effect on productivity, allelopathic interactions and other indicators are to be investigated. Maize as a recognostic plant is to be grown following year 2026 in order to evaluate outcomes of nutrient relay after three years and comprehensive evaluation will be done covering full rotation.

Further more, relay principle will be investigated at an Agroecology project in several countries, BIO-CROP ID:182. Bio-Based Agroecosystem Transitions in the Baltic and Nordic Regions through Integrated Relay Cropping Systems.

RESULTS & DISCUSSION

During the first year of the experiment, winter wheat was grown at multi-crop, with buckwheat, oat, pea or mustard intercropped in spring, and red clover, white clover and vetche undersown in autumn. The following year spring barley was intercropped into red and white clover survived the winter; third treatment was marked by intercropped spring vetche and control treatment was solo barley. Soil structurality and stability were evaluated before drilling and samples were taken after harvesting.

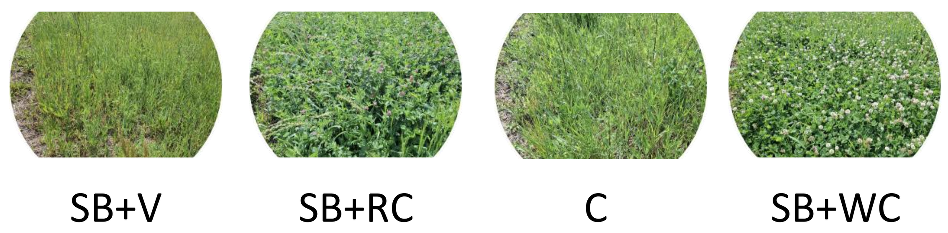

Fig. 3. Four treatments, visual in June, 2025. *C- Control/ Spring Barley, SB+RC – Spring Barley +Red Clover, SB+WC- Spring Barley +White Clover, SB+V – Vetche + SB*

Soil structurality (Fig.4) was evaluated after the 2024 harvest, before seeding in spring 2025, and again after the 2025 harvest. Separate multi-cropping treatments showed varying effects on soil physical parameters.

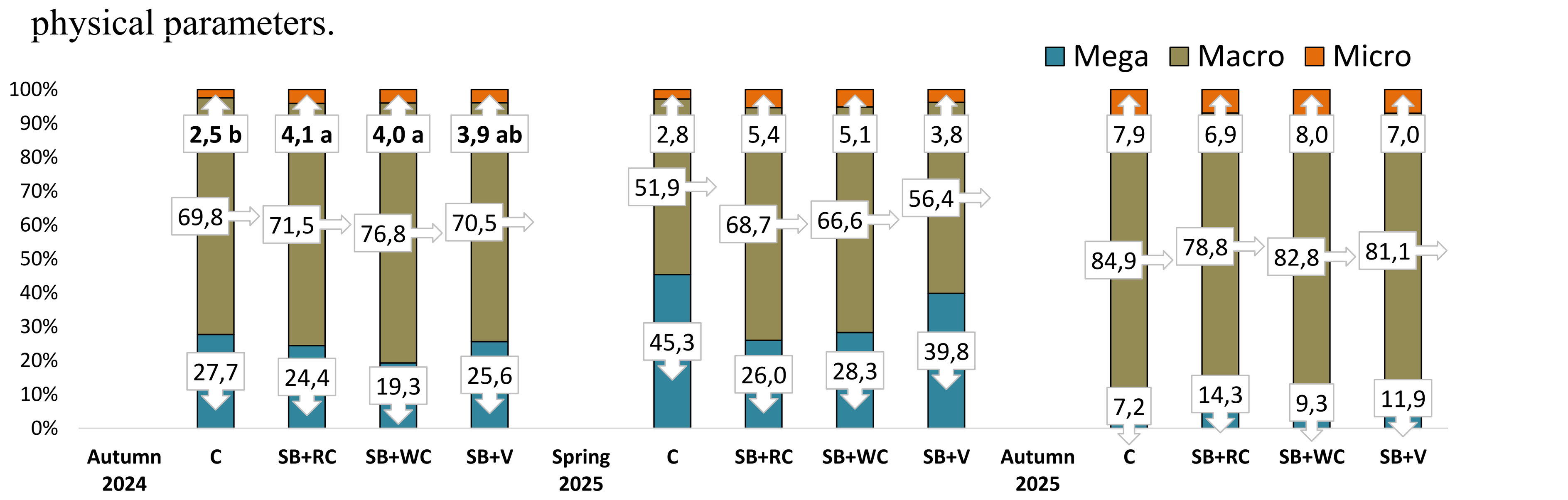

Fig. 4. Soil structure (Mega aggregates, macro aggregates, micro aggregates) 2024 - 2025, %. *C/SB- Control/ Spring Barley, SB+RC – Spring Barley +Red Clover, SB+WC- Spring Barley +White Clover, SB+V – Spring Barley + Vetch*
Note: Differences between the averages marked with different letters (a, b, c) are significant ($P < 0.05$).

No significant differences were observed in macro- or mega-aggregate fractions between treatment at any assessment. However, at the beginning of the trial, the proportion of micro-aggregates differed significantly among treatments, with inter-seeded red clover and white clover exhibiting the highest values. Macroaggregates (0.25–10.0 mm) (Howe and Smith, 2021) are characterized by higher metabolic activity and greater organic matter content. Enhancing soil carbon improves soil structural stability (Moran et al., 2005; Arlauskienė et al., 2009). Thus, the multiple-cropping system used in this experiment is consistent with this mechanism, as shown in Fig. 3, where the proportion of macro-aggregate particles demonstrated a tendence to increase.

Soil stability assessment (Fig. 6) indicated that, after two vegetative seasons, in autumn 2025, the highest values were recorded in the barley intercropped with vetch or red clover treatments; however, these differences were not statistically significant.

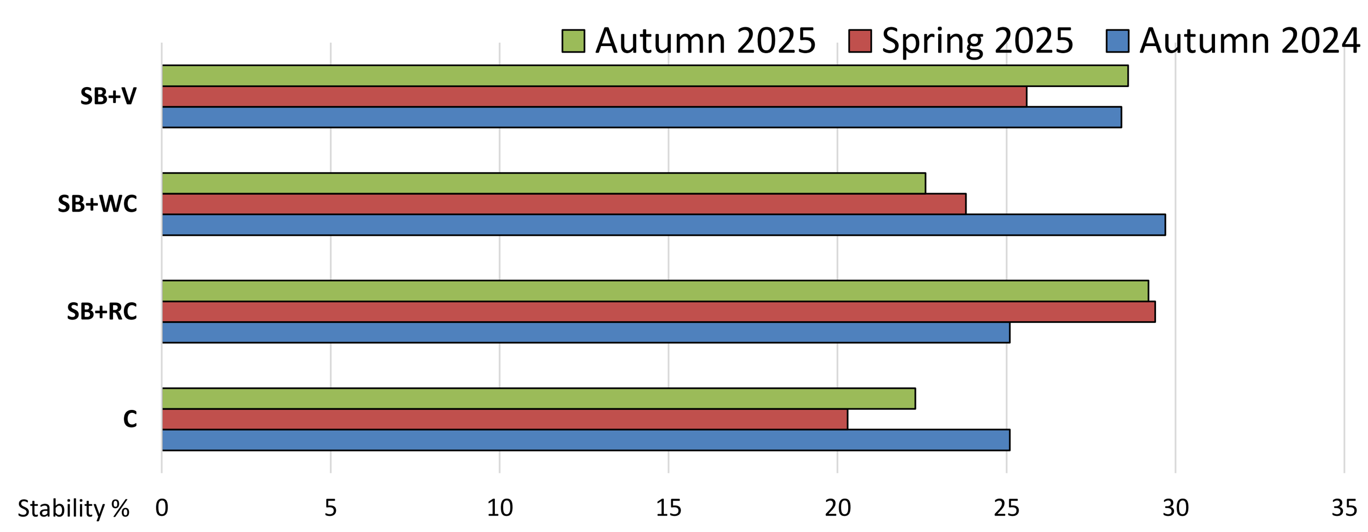

Fig. 6. Macroaggregates, post harvest 2024 vs pre-drilling 2025, %. *C/SB- Control/ Spring Barley, SB+RC – Spring Barley +Red Clover, SB+WC- Spring Barley +White Clover, SB+V – Vetch + SB*

CONCLUSION

Multicropping showed positive impact on soil aggregate structure, increasing macro-aggregate and reduced mega-aggregate, however control followed the same tendency. Soil stability after two multicropping seasons increased, while mono crop barley demonstrated negative impact onto stability. Surprisingly, white clover and barley combination had negative impact also. Impact of nutrient relay is to be evaluated with the assessment of recognostic crop. Two full cycles of rotation are planned in order to draw tendences and advice looking forward Green deal and sustainable or regenerative farming.

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