WHAT ARE THE **ADVANTAGES OF MORE DIVERSITY** IN COVER CROP MIXTURES?

Do I use a single component or a mixture as a cover crop? Are four components in a mixture enough or should there be more? You can find out that there is more than just one correct answer in the summarised results of the CATCHY project.

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Ecosystem studies in recent decades have shown that with an increasing number of crop species in natural habitats, material cycles, water and energy flows become more efficient, pest pressure and disease infestation decrease and, at the same time, carbon sequestration and climate regulation are positively linked. Biodiversity is therefore the key to multifunctional and thus resilient ecosystems. Cover crops are one of the tools that can be used to integrate biodiversity-based functions into arable farming in order to create more resilient cropping systems. Against this background, the CATCHY project began with the hypothesis that biodiverse cover crop mixtures could potentially be superior to pure seeds. By specifically combining crop species with genetic diversity and thus differences in morphological characteristics, nutrient requirements and biomass qualities, mixtures were to be created with the aim of maximising the positive functions of cover crop cultivation.

Which combination delivers what?

The selection of cover crops should represent all important crop families as far as possible: bristle oat the grasses, mustard the crucifers and clover the legumes. Even though phacelia as a waterleaf crop is not related to any of our cultivated crops, it is an important cover crop in practice. These four crop species were tested as pure seeds and in a mixture (Mix4) against a fallow as a control. In addition, a commercial mixture of 12 components with about 25 % legumes in the seed content (Mix12; TerraLife®-MaizePro) was tested. The cover crop variants (pure seeds and mixtures) did not show any statistically significant differences in the yield of their shoot biomass.

The **CATCHY cover crop project** was launched by the Federal Ministry of Education and Research (FMER) in 2015. The universities and institutions that have conducted joint research here include the Leibniz University of Hannover, the Weihenstephan-Triesdorf University of Applied Sciences and Arts, the Leibniz Institute of Crop Genetics and Crop Research Gatersleben or the University of Bremen. The main objective was to examine cover crops as a measure for developing innovative cultivation systems that maintain and improve soil fertility. The following focal points were investigated: The effect on soil structure and quality, the microbiome, the nutrient and water balance as well as the yield effect and profitability. This article summarises all the sub-projects. A closer look at the sub-projects will follow in the next issues of the Innovation.

Cover crop mixtures contribute to balanced crop nutrition.

The mixture Mix12 (TerraLife® -MaizePro) showed the highest potential for nutrient enrichment.

More about CATCHY:

Only the clover developed only about half of the biomass. However, the biomass yields of the mixtures were more stable over the years than those of the pure seeds and were less subject to weather-related fluctuations. Mixtures showed superiority particularly in root development. Between 1.3 and 3.9 tonnes/ha more root biomass was measured in Mix4 compared to the pure seeds. Mixtures showed a further advantage in their nutrient enrichment in shoots and roots (Fig. 1). Typically, crop species have specific nutrient profiles, with higher uptake of certain nutrients and lower uptake of others. For example, among the species analysed in the CATCHY project, mustard was high in S but low in Ca and phacelia was high in P but low in S (Fig. 1). In Mix4, both crop species were combined with bristle oat and clover. Accordingly, Mix4 contained sufficient P and S but also N and K. Mix12 in particular showed the highest potential for enrichment of most macro- and micronutrients. Mixtures thus led to more balanced nutrient ratios in shoot and root and maximised the amount and range of nutrients taken up. Overall, more nutrients accumulated in the biomass of mixtures compared to pure seeds.

Balance at elementary level

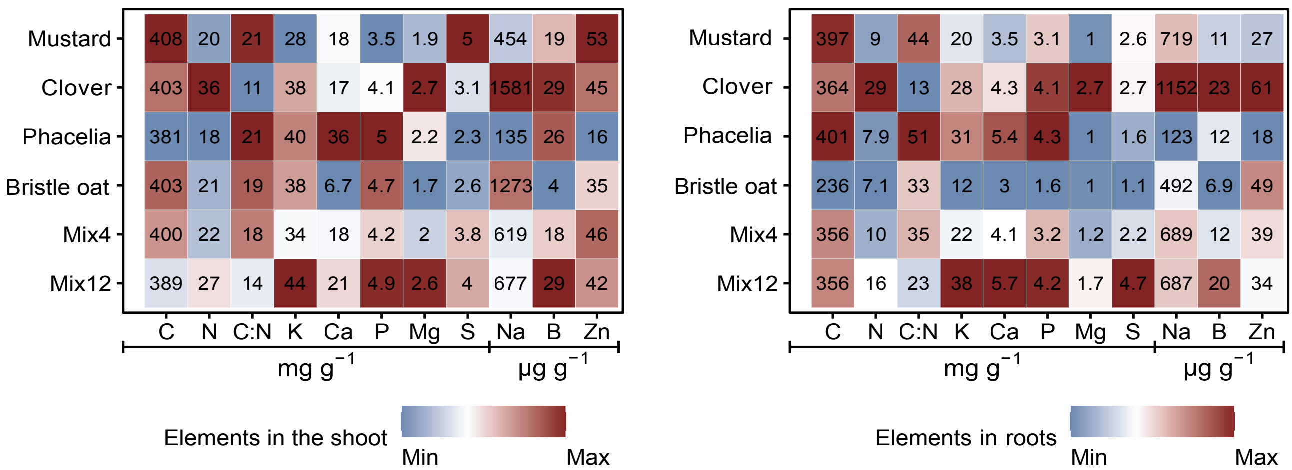
Balanced nutrient ratios are particularly important for the microbial decomposer community and thus for the speed of decomposition and nutrient release. The C/N ratio is one of the most important parameters here. The closer the ratio, the faster litter materials are converted and nutrients mineralised. In decomposition experiments, the results showed that P, K, Ca, Fe and Al are all likewise important for microbial metabolism. Balanced element ratios in the cover crop biomass led to a larger and more diverse microbial biomass during decomposition, which increased in a gradient from pure seeds to Mix4 to Mix12. The more efficient decomposition is reflected in the nutrient pool of the soil and in the nutrient transfer to the subsequent crop. Overall, Mix12 transferred more nutrients and a broader nutrient spectrum to the following crop maize compared to the other variants. This means that cover crop mixtures contribute to a more balanced crop nutrition.

The direct release of substances into the root zone, the so-called rhizosphere, is also decisively influenced by cover crops. Crops release a complex mixture of different substances into the rhizosphere as root exudates. These can contain, for example, carbohydrates, proteins, organic acids, amino acids, hormones, vitamins, enzymes and much more. Among other things, these serve to mobilise nutrients directly, to communicate with microorganisms as their food source, but can also contain antimicrobial substances. Each crop species has a very specific metabolite profile (metabolites = substances that arise as intermediates or as degradation products of metabolic processes of the organism) through which it comes into specific contact with the soil and soil organisms. This means that the combination of different crop species not only produces a mixture of nutrients in the shoot and root mass, but also a mixture of root exudates and their functions.

Microbial fingerprints of cover crops

Crops influence the microbial community in the soil directly via the quality of their litter and through their root exudates. Crops exert indirect influences by changing soil parameters such as pH values, water balance or oxygen availability. The microbial fingerprints of co-

FIG. 1: NUTRIENT ENRICHMENT IN SHOOT AND ROOT BIOMASS OF VARIOUS COVER CROPS IN PURE SEEDS AND IN MIXTURES.



In cover crop mixtures as well as in pure seeds, such as phacelia, micro-organism communities were found in the soil with nutrient mobilisation functions.

ver crops were analysed in samples of root-free soil, in the rhizosphere soil and in the roots of cover crops and subsequent crops. It was clearly shown that crop species differ in the microorganisms that colonise their roots. A large proportion of the microorganisms could be found on all cover crop species. However, there were also specific organisms that only occurred together with certain crop species. For example, Nitrobacter (bacteria involved in nitrogen turnover in the soil) occurred specifically on clover. Each cover crop left behind a specific microbial community in the soil for the subsequent crop.

The soil does not forget

The young seedlings of the subsequent crop recruit their microbiome primarily from the soil. This means that the vegetation history is important for the microbiome in and on a crop. The higher the microbial diversity in the soil, the more diverse the groups of microorganisms from which the crops can choose. The root microbiome is important for metabolic processes and the nutrient utilisation of the crop. In fact, certain microorganisms were only found in the maize roots after very specific cover crops, or occurred there more frequently. To this end, taxonomic analyses were carried out on the composition of fungal and bacterial genera in maize roots. There was a tendency for a higher fungal diversity to be found not only in the soil but also in the roots of maize crops after cover crop mixtures compared to pure crops and fallow. Especially after Mix12, bacterial communities with a positive influence on the nitrogen cycle were measured in maize roots. Overall, however, microbial communities with functions for nutrient mobilisation, as biocontrol agents against pests, insect pests or nematodes were found not only in the cover crop mixtures, but also in pure seeds (especially phacelia), which were not found after fallow. The results show that cover crops can be a practical means of actively influencing microbial communities in the soil and within crop rotations. However, the results are not yet sufficient to derive generally applicable recommendations for the composition and use of cover crop mixtures. In the project, we were only able to analyse a few of thousands of conceivable crop combinations in detail. There is still a lack of comprehensive studies on the influence of individual crop species, their behaviour in mixtures and the influence on the microbial community at different locations

Activation of the microbial „C-pump“

The formation of humus and the increase in C_{org} in the soil are strongly dependent on how efficiently the microbial community uses the inputs via the shoots and roots of the cover crop. This means that the quality of the food base for soil organisms determines how much C is mineralised and leaves the soil as CO_2 or remains in the soil as C_{org}. It is only through microbial metabolism that stable humus compounds are formed, which make up the majority (>80 %) of the humus body. The sooner the litter meets the nutritional needs of the microbial community, the more efficiently they will work. It is not a maximum C content in the cover crop that is decisive for humus formation, but the right ratio of C to N, P or K. Here it was shown that Mix12 and clover in particular activated the „microbial C pump“ very efficiently and increased the C_{org} transfer into the humus body. But all other variants also led to slight humus build-up compared to fallow land. The final C_{org} inventory is still in progress.

Conclusion

Cover crop mixtures are not necessarily superior in every function to the correspondingly best individual components in pure seeds. We often only measure small differences that cannot always be statistically verified. Nevertheless, many small effects add up to a large one and can be described as multifunctionality. A targeted combination of cover crop species - based on the principles of ecosystem theory - can establish itself as a sustainable and economically sensible tool for optimising the material cycles in the crop-soil-microbiome system. However, there is still a long way to go in research before the soil microbiome can be specifically influenced by cover crops („bioengineering“) and the resulting improvement of yield and quality.

Nine years of cover crop research in the CATCHY project have produced exciting and sometimes unexpected results, but have also raised many new questions. We are at the beginning of a new perspective on cover crop cultivation. Cover crops are more than just a measure to reduce soil erosion and nutrient losses, they are a multifunctional tool to influence processes in the soil in a targeted manner.