Nature or nurture?

Joint TEAGASC/Italian research from the National Research Council examined nutrient cycling and supply for sustainable grassland production.

Soil nutrient efficiency challenge

In Ireland the total agri-food sector is worth approximately €12.93 bn and, of this, primary production contributes €4.19 bn, which is the main support to Ireland's rural economy. Grassland management plays an important role. Grasslands are central to the cycling and sequestering of nutrients, which can ultimately lead to global environmental benefits. However, the current levels of nutrient-use efficiency (carbon (C), nitrogen (N) and phosphorus (P)) in grazed grassland systems has been shown to be relatively low (26 % for N and 65 % for P in 2015) at a national scale (Eurostat, 2015). Low nutrient-use efficiency has implications for farm profitability, as fertiliser nutrients represent one of the main input costs, at approximately €565 m in total for Irish farms. In addition, the recovery of nutrients by grassland, which are then turned into milk or meat, leads to more sustainable production in terms of protecting water quality and reducing gaseous emissions. However, intensively managed grassland-based farming systems in Ireland occur across different soil and climatic conditions and hence, nutrient efficiency varies widely from farm to farm and field to field. The need for soil-specific understanding of nutrient supply and the fate of added fertiliser nutrient resources is critical to improve the nutrient efficiency, profitability, and environmental sustainability of farms. Additionally, the importance of nutrient efficiency and low environmental footprint for the marketability of Irish food across the world is critical. This implies better management of nutrients for grassland systems in order to minimise the dependence on external fertiliser inputs.

Unlocking the biological potential of soils

Soil provides a range of ecosystem services (hereafter soil functions): (i) production of food, fibre and fuel; (ii) carbon sequestration and mitigation of climate change; (iii) water purification and regulation; (iv) nutrient storage and cycling; and, (v) habitat for biodiversity, the largest store of life on earth. It is well known that grassland soils have the capability to perform multiple functions simultaneously and that this delivery is predominantly controlled by soil biology, with variations upon different environmental and management conditions.

Researchers from Teagasc and the National Research Council in Italy are collaborating on a project, GrassGEN, which will assess the capability of grassland soils to cycle and supply nutrients and unlock the biological potential of Irish grassland soils to deliver important soil functions.

GrassGEN is investigating 20 permanent grassland soils from across the five major agro-climatic regions of Ireland. These soils represent the main mineral soil groups under grassland management identified during the Soil Quality Assessment Research (SQUARE) project (https://www.teagasc.ie/environment/soil/research/square/), and cover a range of scenarios combining different: (i) intrinsic soil characteristics; (ii) spatial/climatic conditions; and, (iii) grassland management type and intensity.

Genetic fingerprinting of grassland soils

The capacity of microbiota to mineralise nutrients stored in soils is a function of their genetic potential and their access to usable forms of

substrates stored in organic matter. Furthermore, the expression of the genes responsible for the synthesis of relevant enzymes may be altered by external factors (i.e., management and climate). GrassGEN aims to develop a genetic fingerprint for grassland soils, which will be used to disentangle the microbiologically mediated transformations, cycling and fate of nutrients. Cutting-edge approaches and technologies, not routinely used in soil and environmental science, will be used:

- genetic approach;
- stable isotopes nutrients dynamics approach; and,
- functional diversity approach.

GrassGEN will elucidate the knowledge gap that exists between the expression of a biochemical function (e.g., enzyme reaction product) and the genetic potential that the soil microbiota actually has to deliver that function. Focused experiments applying genetic technologies for soil microbial diversity will identify response thresholds for nutrient cycling in soil. Stable isotopes of C and N will be used in tracing experiments to identify if a soil has the genetic potential to fully accomplish its biochemical function, or if that potential has been altered by the nutrient inputs. Using these cutting-edge approaches, we will answer some questions on whether it is the nature of the soil or its continuous nurturing that makes grasslands function to an optimal level.

Extracellular enzyme activities

The soil extracellular enzyme activities (EEA) provide a frame of reference for comparing ecosystems and a chance to relate the soil microbial community function to patterns of nutrient dynamics and soil organic matter storage within agricultural landscapes. The demand for nutrients by the soil microbiology can be linked with both the storage and supply of C, N and P in grassland soils. Investigating the C, N and P stoichiometry of the microbial biomass in relation to concentrations of specific nutrients in the soil is used to assess this demand. In addition, identifying the relationships between the enzymes present and the composition of soil organic matter will provide new insights on soil carbon storage and the potential for native soil nutrient release through mineralisation processes. During the initial phase, the GrassGEN project measured soil microbial biomass and EEA to investigate microbial nutrient demand and organic matter decomposition. The measured enzymes related to C, N and P cycles were β-glucosidase, β-N-acetylglucosaminidase and phosphatase, respectively, and varied in relation to different soil types and drainage characteristics, and potentially due to management.

Benefit to stakeholders

GrassGEN will provide the basis for future knowledge transfer and advice for farmers to better manage the rate, type, timing and placement of fertiliser applications for optimum soil fertility and sustainable production on grassland soils. The knowledge developed will underpin sustainable and environmentally friendly soil management strategies for farmers and the wider agricultural industry.

GrassGEN will provide farmers and land managers with the necessary knowledge and information to exploit agricultural soils in a sustainable manner into the future.

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