BONARES
Centre for Soil Research

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Virtual LTE Workshop 2020

LTE research - methods, standardisation and modelling.

1 to 2 October 2020

Abstracts

SPONSORED BY THE

Federal Ministry of Education and Research

Preface

Soil is a limited resource for agriculture, and its productivity can be greatly influenced by farm management. Therefore, it is important to expand the scientific understanding of soil ecosystems and to develop strategies for sustainable use of the soil. The ***BonaRes Centre for Soil Research***, funded by the Federal Ministry of Education and Research (BMBF), is dedicated to this goal and deals with the transfer of new knowledge about soil functions into scientifically based decision-making tools for soil management.

Long-term experiments (LTEs) also play an important role in this research, in which the effects of different long-term soil management strategies on the soil ecosystem can be investigated. In order to better utilize the potential of these experiments, they should be recorded in a repository according to uniform standards and carried out according to scientifically founded methods.

The aim of this virtual workshop is to exchange experiences about the application of modern standards in LTEs and to derive recommendations for the use of these trials for ecosystem research and modelling. The workshop will discuss the requirements for statistical evaluation and data acquisition of LTEs, and methods and selected results of biological, chemical and physical soil parameters will be presented.

At the LTE workshop, the results and experiences from ongoing LTE research will be presented from the perspective of different area of expertise and scientific disciplines. In a total of five sessions, on the one hand, overview articles about LTEs running over many years in Germany, Great Britain and Denmark are given and the possibilities of international networking are highlighted. In addition, the requirements for implementation and data collection in LTEs are explained from the modelling perspective. An important focus of the workshop is the assessment of the microbiome in the soil, which is influenced by soil properties, climate factors and soil management. The results presented on this topic come from classic LTEs as well as from a 20-year FACE experiment in which the effect of increased CO_2 levels in the atmosphere is examined. In a further session, the challenges to the statistical evaluation of LTEs will be discussed. This aspect is important because LTEs are usually very old and have undergone changes over time for technical, climatic or scientific reasons, which should be taken into account in the statistical evaluation. Another focus of the workshop are questions of the effects of crop rotation as well as organic and mineral fertilization on soil properties and crop yields. Here, scientists from Germany, Poland, Hungary, Denmark and Great Britain report on selected results on these topics from their own LTEs. In a final session, the problems occurring in LTEs and the requirements for LTEs are discussed and conclusions for a possible standardization of LTEs are derived.

Bernd Honermeier — Gießen, October 2020

LTE in Germany: Digging, organizing and distributing an agricultural data treasure

Meike Grosse and Carsten Hoffmann
Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany
meike.grosse@zalf.de

Agricultural long-term field experiments (LTE) are a most valuable research infrastructure to reveal the effects of agricultural management in the long run. Beyond the original research question of each LTE the combined analysis of different experiments can be even more valuable, e.g. to answer questions of climate change, ecosystem services, nutrient cycles, or yield stability. However, information about existing LTE is scattered and the data are often not easy to access.

The definition of LTE in the context of BonaRes (short for "Soil as a Sustainable Resource for the Bioeconomy") is a minimum duration of twenty years, a static design and a focus on soil and yield parameters. According to this definition in total 205 LTE across Germany were identified, of which 140 trials are ongoing and 65 are finished. The majority are field crops experiments (168 field crops LTE, 34 grassland LTE, 3 vegetable or pomiculture LTE). 92 % of the LTE are managed conventionally and 78 % are fertilization experiments.

An important information tool is the compilation of all existing LTE in Germany with metainformation to each trial. This information is shown in a dynamic online overview map, which is available in German and English (https://ltfe-map.bonares.de). The map offers overview information about the LTE as well as detailed information, offering valuable information for potential users for orientation and initiation of cooperation.

An assessment of the spatial distribution of LTE according to different environmental conditions in Germany was done to achieve a sound basis for future common analyses. Meta-information about all LTE was categorized according to the three main research themes fertilization, tillage, and crop rotation. The spatial distribution of LTE was analysed on the basis of the climatic water balance (CWB) and the soil quality according to the Müncheberger Soil Quality Rating (MSQR). Results showed that the distribution of LTE is biased towards dry areas with low CWB, in particular the very low CWB class 1. Regarding soil quality, the distribution of LTE is biased towards high and very high MSQR classes, whereas low and medium MSQR classes are underrepresented. However, nearly every CWB and MSQR class is represented by at least some LTE.

Scientific data re-use is hindered by the difficult access to widely scattered LTE research data, different data structures, formats and documentations. The establishment of a data repository with standardized database structures, metadata description by DataCite and INSPIRE elements, the annotation of AGROVOC keywords and the open data access via the BonaRes Portal are four of the key elements, served by the BonaRes Repository, to meet the requirements of modern FAIR data principles.

Current activities of global long-term agricultural experiment network (GLTEN)

Carolina Cardoso Lisboa[1)], Jonathan Storkey[1)], Richard Ostler[2)], Andrew Mead[2)]

[1)]Sustainable Agriculture Sciences, Rothamsted Research, United Kingdom

[2)]Computational and Analytical Sciences, Rothamsted Research, United Kingdom

carolina.lisboa@rothamsted.ac.uk

The Global Long-Term Agricultural Experiment Network (GLTEN) was launched in October 2019 with the aim of collating and harmonising metadata on LTEs from across the global and covering all the major cropping systems. The experiments currently included in the GLTEN-Metadata Portal (https://glten.org/) represent a range of climates, environments, crop systems and farming practices. The establishment of the GLTEN has been guided by the FAIR Data Principles (findable, accessible, interoperable, re-usable). However, the initial focus has been on expanding the portfolio of experiments and so increasing LTEs 'findability'. This will be particularly important for countries that have lacked resources for funding networking activities of this type in the past. The suite of LTEs in the network is currently being used to demonstrate the functionality of the online GLTEN for discovering experiments with similar or contrasting treatments to provide the evidence for alternative strategies and possible analytical techniques for combining different datasets. In this aspect, the GLTEN has received positive support from the agricultural science community in recognizing the potential of combining LTEs-datasets in the pursuit of sustainable and resilient global food production systems. Making LTE data (and, in some cases metadata) 'accessible', 'interoperable' and 're-usable' is a much bigger, longer term challenge and experience of working with LTE datasets as part of GLTEN has highlighted the need for effective training in data management, particularly in the developing world. At the same time, there have been a rapidly progress within the scientific community in this area. The GLTEN is making this a focus as we develop scientific collaborations among the international scientific community through supporting grant applications and providing guidance on issues related to LTE data management and data analysis.

The Rothamsted Long-term Experiments

Andrew J. Macdonald[1)], Paul R. Poulton[1)], Sarah A. M. Perryman[2)] and Margaret J. Glendining[2)]

[1)]Department of Sustainable Agriculture Sciences,

[2)]Department of Computational and Analytical Sciences,

Rothamsted Research, Harpenden, Herts AL5 2JQ, UK

andy.macdonald@rothamsted.ac.uk

The Rothamsted "Classical" field experiments were established by Lawes and Gilbert between 1843 and 1856, to study the effects of fertilisers and manures on crop production. Some of these experiments continue today and form part of Rothamsted's Long-Term Experiments National Capability. Their initial aims were achieved relatively quickly, but subsequently they have been modified to include the use of lime, pesticides and new crop varieties to ensure that they remain relevant to current agricultural issues, whilst maintaining their long-term integrity.

Two of the best known long-term experiments at Rothamsted are the Broadbalk Wheat and Hoosfield Barley experiments. On Broadbalk, yields of winter wheat in rotation, receiving farmyard manure (FYM) and mineral nitrogen (N), or mineral N plus PKMg, continue to increase after >175 years of cropping. The highest yield of 13 t ha^{-1} was recorded on Broadbalk in 2014 when a new high-yielding variety (*cv* Crusoe) was grown. Such high yields require large amounts of N fertiliser. In contrast, large annual applications of FYM alone cannot supply enough N for maximum yield.

On Hoosfield, yields of spring-sown barley also responded to the change to short-strawed cultivars in 1970, larger amounts of N and the use of fungicides since 1978. However, in contrast to the wheat on Broadbalk, maximum yields are only obtained where soil organic carbon (SOC) has been increased through applications of FYM, illustrating the importance of SOC for good soil structure and the rapid root growth needed by spring-sown crops to acquire water and nutrients within a short growing season.

These experiments, and others at Rothamsted, demonstrate that, providing nutrient offtakes are replaced, soils are appropriately limed and drained, crop yield is protected by herbicides and fungicides, and new varieties are used, conventionally managed arable soils in the UK can continue to be productive for over 175 years.

Long-term yield variability trends for winter wheat and spring barley: insights from the Askov LTE in Denmark

Janna Macholdt[1),2)], Steffen Hadasch[3)], Hans-Peter Piepho[3)], Moritz Reckling[4)], Arezoo Taghizadeh-Toosi[5)], Bent T. Christensen[5)]

[1)] Institute of Agronomy and Plant Breeding I, Justus Liebig University Giessen, Germany

[2)]Section of Environmental Chemistry and Physics, Department of Plant and Environmental Sciences, University of Copenhagen, Denmark

[3)]Biostatistics Unit, Institute of Crop Science, University of Hohenheim, Fruwirthstrasse 23, 70599 Stuttgart, Germany

[4)]Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Strasse 84, 15374 Muencheberg, Germany

[5)]Department of Agroecology - Soil Fertility, Aarhus University, Blichers Allé 20, 8830 Tjele, Denmark

janna.c.macholdt@agrar.uni-giessen.de

The design of resilient cropping systems with low temporal yield variability (or rather high yield stability) is becoming increasingly important due to current and future climatic and agronomic challenges. Consequently, it is essential to evaluate the yield stability of different crops over the past decades under different agronomic management practices. Long-term experiments are a valuable resource for investigating the effects of climate and management, as they provide enough time to accurately estimate temporal yield variability and its trend over years. The objective of this study was to provide a novel comparison of spring barley and winter wheat as globally important spring and winter cereals, regarding their trends in temporal yield variability at different levels of mineral (50%/100%/150% NPK) and organic fertilizer (50%/100%/150% manure). Yield data from the Askov long-term experiment (Denmark) during 1932 to 2019 were analysed using a mixed model approach with REML (restricted maximum likelihood) based and refined Shukla`s stability variance estimations. Across all fertilization treatments, winter wheat showed lower temporal yield variability than spring barley during the analyzed experimental period from 1932 to 2005. Within the recent period (2006-2019), an increase in wheat yield variability over time has been observed; this trend was much less pronounced in spring barley. Therefore, wheat yields became less stable than barley yields during this last decade. The results further showed that wheat and barley yields were fluctuating more under higher fertilizer levels (100%/150%), and, in vice versa, a better yield stability has been observed under a reduced nutrient input (50%). Animal manure led mostly to more stable yields than mineral NPK, this effect was evident for wheat and barley equally. The resilience of cropping systems is consequently affected by the choice of the crop, the amount and type of fertilization, and changes in climate.

What do modellers expect from LTEs?

Sara König, Hans-Jörg Vogel, Uli Weller, Ute Wollschläger
Helmholtz Centre for Environmental Research (UFZ) Halle, Germany
sara.koenig@ufz.de

Mechanistic simulation models are an essential tool for predicting the influence of changing external factors on ecosystem functions. For estimating the various functions in agricultural soil systems, knowledge about the long-term effects of different land management activities is mandatory.
In this contribution, we will discuss the importance of long-term field experiments for the development of systemic soil models capable to simulate the dynamics of soil functions. This is demonstrated for the */Bodium/* model, which integrates biological, physical and chemical processes to predict the effect of management activities on soil functions. For validating the simulated outcomes, data of long-term field experiments are essential. Such data are indispensable to gain a systemic understanding of soil processes, which is highly required to evaluate the impact of soil management on soil functions.
Towards a future perspective, we want to highlight how additional measures of soil properties in long-term field experiments with a well-known land management history can provide valuable input for the development of new systemic modelling approaches.

What have we learned from the Giessen FACE grassland after 20 years of elevated CO_2?

Gerald Moser, Christoph Müller
Institute for Plant Ecology, Justus Liebig University Giessen, Germany
gerald.moser@bio.uni-giessen.de

The Giessen FACE experiment in a permanent, extensively managed grassland started in May 1998 and is still active. It is one of the longest running Free Air CO_2 Enrichment = FACE experiments worldwide and some unique long-term datasets have been recorded. The +20% CO_2 enrichment is active during day time hours all year long. The grassland is cut twice a year and is fertilised with 40 kg N per year. Over more than 20 years many different climatic conditions and extreme events occurred that made it possible to observe the CO_2 fertilization effect under wet to dry and cool to hot conditions. Highest yield increases under elevated CO_2 have been observed under average climatic conditions, but significant reductions in the CO_2 fertilization effect occurred during or after extreme events. But not only the biomass yield reacted to increased CO_2 availability, but also the fodder quality showed changes. The protein content under elevated CO_2 decreased, while the raw fibre content was increased, causing reduced digestibility. This grassland ecosystem showed not only aboveground changes, but also some significant belowground changes in carbon and nitrogen fluxes. Since 1998 the fluxes of the greenhouse gases CO_2, CH_4 and N_2O have been measured weekly. It was observed that under elevated CO_2 increased emissions of CO_2 and N_2O occurred simultaneously with reduced CH_4 uptake. These changes of in greenhouse gas fluxes are the reason that this grassland shifts under elevated CO_2 from a sink to a source of greenhouse gases. If this positive feedback reaction to climate change occurs also under increased temperature combined with elevated CO_2 concentrations is now under investigation in a new two yearlong running combination experiment called the Giessen T-FACE (Temperature warming and Free Air CO_2 Enrichment).

Elevated atmospheric CO_2 modifies mostly the active rhizosphere soil microbiome in the Giessen FACE experiment

David Rosado-Porto[1),5)], Stefan Ratering[1)], Massimiliano Cardinale[2)], Corinna Maisinger[1)], Gerald Moser[3)], Christoph Müller[3),4)], Sylvia Schnell[1)]

[1)]Institute of Applied Microbiology, Justus Liebig University Giessen, Germany

[2)]Department of Biological and Environmental Sciences and Technologies, University of Salento, Via Prov.le Monteroni, I-73100 Lecce, Italy

[3)] Institute of Plant Ecology, Justus Liebig University Giessen, Germany

[4)]School of Biology and Environmental Science and Earth Institute, University College Dublin, Belfield, Dublin, Ireland

[5)]Simón Bolívar University, Faculty of Basic and Biomedical Sciences, Barranquilla, Colombia

sylvia.schnell@agrar.uni-giessen.de

Elevated levels of atmospheric CO_2 lead to the increase of plant photosynthetic rates, carbon inputs into soil and root exudation. In this work, the effects of rising atmospheric CO_2 levels on soil ecosystems have been investigated at the Giessen free-air CO_2 enrichment (Giessen FACE) experiment on a permanent grassland site near Giessen, Germany. The aim was to assess the effects of increased C supply into the soil, due to elevated CO_2, on the active soil microbiome composition. RNA extraction and 16S rRNA (cDNA) Ion Torrent sequencing were performed from bulk and rhizosphere soils, and the obtained metabarcoding data were processed for calculation of diversity indices and co-occurrence network analysis. The structure of the active microbiome in the rhizospheric soil showed a clear separation between elevated and ambient CO_2; CO_2 concentration exerted a strong influence on the microbiomes differentiation. In contrast, elevated CO_2 had no significant influence on the structure of the bulk soil microbiome. Network analysis showed that several stimulated OTUs were highly clustered and formed a subnetwork under elevated CO_2 conditions. Our data clearly show that the ongoing atmospheric CO_2 increase of climate change will significantly shift the microbiome structure in the rhizosphere.

Soil microbiota and the health of plants

Doreen Babin[1)], Narges Moradtalab[2)], Jan Behr[3)], Soumitra Paul Chowdhury[4)], Loreen Sommermann[5)], Lorrie Maccario[6)], Søren J. Sørensen[6)], Annette Deubel[5)], Michael Rothballer[4)], Joerg Geistlinger[5)], Günter Neumann[2)], Kornelia Smalla[1)], Rita Grosch[3)]

[1)]Julius Kühn-Institut, Federal Research Centre for Cultivated Plants (JKI), Institute for Epidemiology and Pathogen Diagnostics, Braunschweig, Germany

[2)]University of Hohenheim, Institute of Crop Science (340h), Stuttgart, Germany

[3)]Leibniz Institute of Vegetable and Ornamental Crops (IGZ), Großbeeren, Germany

[4)]Institute of Network Biology, Helmholtz Zentrum München, German Research Center for Environmental Health, Germany

[5)]Anhalt University of Applied Sciences, Department of Agriculture, Ecotrophology and Landscape Development, Bernburg, Germany

[6)]University of Copenhagen, Department of Biology, Section of Microbiology, Copenhagen, Denmark

grosch@igzev.de

Conventional agricultural practices based mainly on the input of synthetic fertilizer and pesticides which have increased productivity, but has resulted in a number of negative impact on soil functioning and quality. Nearly all relevant soil processes are microbe-mediated and are key factors for soil functions and plant productivity. A better understanding of soil-plant-microbe interactions in agroecosystems may pave the way towards a more sustainable agriculture. We therefore aimed to study the effect of different long-term farming practices on the soil and rhizosphere microbiota as well as plant performance (growth, health, root exudates). A long-term field experiment in Bernburg (Germany, 1992) served as study site, which allows comparing of two soil management practices (mould-board plough vs. cultivator tillage) as well as nitrogen fertilization intensities (intensive fertilization including fungicides vs. reduced extensive fertilization without fungicides). Soil samples were collected from the different treatments and the model plant lettuce (*Lactuca sativa*, L. cv. Tizian) cultivated in the respective soil samples for 10 weeks under controlled climate chamber conditions. High-throughput sequencing of bacterial 16S rRNA genes or fungal ITS fragments, respectively, PCR- amplified from total community DNA of rhizosphere and soil samples showed significant differences in microbial community compositions depending on the long-term farming practices. Moreover, differences depending on long-term agricultural management in plant growth and health as measured by RT-qPCR of stress-related plant genes were observed. Quantity and quality of lettuce root exudates differed among the soil treatments and indicated different stress potentials of farming practices on plants. Under controlled growth chamber conditions, we could show that the lettuce rhizosphere microbiota assemblage as well as plant growth and health are significantly influenced by farming practices. We suggest a farming-dependent legacy on the performance of the subsequent crop generation via belowground plant-microbiota interactions.

Statistical challenges in the design and analysis of LTE

Hans-Peter Piepho
Biostatistics Unit, Institute of Crop Science, University of Hohenheim, Fruwirthstrasse 23, 70599 Stuttgart, Germany
piepho@uni-hohenheim.de

Long-term experiments (LTE) provide a priceless basis for agricultural research. Their great value gains particular importance in current efforts to understand and mitigate the processes underlying climate change.
The design of LTE poses particular challenges, due to the longitudinal nature of such trials. In this contribution, I will briefly review some of the basic principles of experimental design and how they apply to LTE. Several of the key LTE available to date were laid out at a time where either classical principles of experimental design as considered standard to date were not yet in mainstream thinking at the time these LTE were started. Some of these use systematic designs. We will also revisit the rationale underlying such systematic designs and the implications for analysis and inference. Since the workshop is hosted in Giessen, it seems more than appropriate to revisit Mitscherlich's (1919) method and its extension by von Boguslawski (1942), who started several LTE in research stations of the Justus Liebig University Gießen (sites in Gießen and in Rauischholzhausen).
As regards analysis, longitudinal data are best analysed using linear mixed models that can account for serial correlation of observations on the same plot. We will review such models and how they can be applied to field trial data in general (Piepho et al., 2014) and LTE in particular (Onofri et al., 2016). Particular emphasis will be given to approaches that allow accounting for long-term time trends in both mean response as well as variability of responses (Hadasch et al., 2020). Assessing trends in variability is of particular importance when it comes to assessment of yield stability and risk under changing climatic conditions (Macholdt et al., 2020).

References

Hadasch, S., Laidig, F., Macholdt, J., Bönecke, E., Piepho, H.P. (2020): Trends in the mean performance and stability of winter wheat and winter barley yields using a long-term series of variety trials. *Field Crops Research* **251**, 107792.

Macholdt, J., Styczen , E.M., Macdonald, A., Piepho, H.P., Honermeier, B. (2020): Yield stability and yield risk of winter barley – a long-term analysis from a cropping system perspective. *European Journal of Agronomy* **117**, 126056.

Mitscherlich, E.A. (1919): Vorschriften zur Anstellung von Feldversuchen in der landwirtschaftlichen Praxis. Verlag Paul Parey Berlin 1919; 2. Aufl. 1925.

Onofri, A., Seddaiu, G., Piepho, H.P. (2016): Long-term experiments: case studies on data analysis. *European Journal of Agronomy* **77**, 223-235.

Piepho, H.P., Büchse, A., Richter, C. (2004): A mixed modelling approach to randomized experiments with repeated measures. *Journal of Agronomy and Crop Science* **190**, 230-247.

von Boguslawski, E. (1942): Die "Ertragsflächenmethode" zur gegenseitigen Abstufung von zwei Untersuchungsfaktoren im Feldversuch. *Pflanzenbau* **18**, 129-149.

Analysis of a long-term nitrogen fertilization experiment on fen grassland

Bärbel Kroschewski[1)], Christel Richter[1)] and Jürgen Pickert[2)]

[1)]Albrecht Daniel Thaer Institute for Agricultural and Horticultural Sciences, Humboldt-Universität zu Berlin, Germany

[2)]Leibniz Centre for Agricultural Landscape Research (ZALF) Müncheberg, Germany

b.kroschewski@hu-berlin.de

A long-term field experiment with five nitrogen (N) fertilization treatments (annual N rates of 0, 60, 120, 240 and 480 kg N ha^{-1}) has been continuously conducted on drained fen grassland since 1961. The trial was established in a randomized complete block design with four replications. Since 1971 all plots were cut three times annually, and one third of the N fertilizer amount was applied to every cut. Dry matter (DM) yields of all cuts were measured during the entire experimental period.
The aim of the experiment was to study the impact of different N rates on the DM yield and to derive practical conclusions for drained fen grassland management. It could be expected that DM yields would depend not only on nitrogen but also on annually varying water conditions, and internally changing physical soil characteristics due to drainage. Therefore, the incorporation of further information about typical characteristics of the drained fen soil at plot scale is necessary. In 2015, peat layer thickness, dry bulk density, and elevation (describing the different distances between sward and ground water table beneath the trial area) were recorded for each plot separately.
As a first step, DM yield (per cut and total) was regressed on N rate (linear, quadratic), elevation, peat layer thickness and dry bulk density with models per each year using multiple linear regression (SAS 9.4 software, proc REG and MIXED) for the period from 1971 to 2016. We fitted the full model and all possible sub-models, and model fits were evaluated by Akaike Information Criterion and adjusted R^2. The N rate affected DM yield variously between the years as well as between the cuts. We could not find a similar pattern for all years (no as well as a linear or a non-linear N effect). The impact of the various soil characteristics on the DM yield differed too. Especially, elevation enhanced the model fit but peat layer thickness and dry bulk density were also often incorporated in the best model, either separately or in common.
As a second step, a joint regression function will be fitted for years with similar growing conditions. Therefore, the annual growth periods per cut were characterized by number of growing days, temperature sum, precipitation sum (daily weather data recorded since 1978), and average groundwater level (recorded since 2005).
In addition, the long-term trends of DM yields per cut and total DM yield for all nitrogen treatments are of interest. Due to the high annual variation of yields, an appropriate statistical model should incorporate characteristics of annual growth periods.

Effects of crop rotation and fertilization on yield stability – experiences from the Broadbalk Wheat Experiment Rothamsted and the Crop Rotation Experiment Rauischholzhausen (University Giessen).

Janna Macholdt[1),2)], Merete E. Styczen[2)], Hans-Peter Piepho[3)], Bernd Honermeier[1)], Sarah Perryman[4)], Andrew Macdonald[5)] and Paul Poulton[5)]

[1)] Institute of Agronomy and Plant Breeding I, Justus Liebig University Giessen, Germany

[2)]Section of Environmental Chemistry and Physics, Department of Plant and Environmental Sciences, University of Copenhagen, Denmark

[3)]Biostatistics Unit, Institute of Crop Science, University of Hohenheim, Germany

[4)]Department of Computational and Analytical Sciences, Rothamsted Research, UK

[5)]Department of Sustainable Agriculture Sciences, Rothamsted Research, UK

janna.c.macholdt@agrar.uni-giessen.de

The development of resilient cropping systems with high yield stability in the face of a changing climate is becoming increasingly important. In particular, it is essential to understand the effects of different agronomic management practices, such as crop rotation and fertilization, on the stability of crop yields. Long-term experiments are a valuable resource for investigating these effects, as they provide sufficient time to estimate stability parameters. The objective of this study was to compare the effects of crop rotation, mineral N fertilization, and organic manure additions on the yield stability of winter wheat and winter barley, using yield risk (the probability of yield falling below a threshold yield level) and inter-annual yield variability as stability indicators. Long-term yield data from the Broadbalk Wheat Experiment 1986-2017 (Rothamsted Research, UK) and the Crop Rotation Experiment Rauischholzhausen 1993-2019 (University Giessen, Germany) were analysed using mixed models giving residual maximum likelihood estimates including Shukla's stability variance and Eskridge's risk assessment approach.

The results of the Broadbalk Wheat Experiment[(a)] showed that rotational cropping combined with sufficient mineral N fertilizer, with or without organic manure, ensured stable wheat yields while reducing yield risk. In contrast, higher yield risks and inter-annual yield variabilities were found in continuous wheat sections with less mineral N fertilizer or with organic manure only. When straw was incorporated and wheat received inputs of manure, the inter-annual yield variability was lower and yield risk was higher than when straw was removed. When inorganic N only was applied, straw management did not appear to have an effect on yield risk, but did on inter-annual yield variability. Wheat yields were more stable when straw was removed than when it was incorporated, especially when wheat received more mineral N fertilizer. However, the impact of straw management (removal v. incorporation) when wheat was grown continuously was not conclusive and warrants further investigation.

The results of the Crop Rotation Experiment Rauischholzhausen[(b)] showed that winter barley grown in rotations dominated by cereals had lower inter-annual yield variability and greater production risks compared with barley grown in rotations with higher crop diversity and additional organic matter inputs. When barley yields were compared at three levels of mineral N, the highest yield stability was achieved with the medium amount of N (70 kg N ha^{-1}), followed by the higher level of N (140 kg N ha^{-1}). The most unstable yields with the highest production risks were observed when barley was grown without any mineral N fertilization.

Overall, the results of both LTEs indicated that lower inter-annual yield variability does not automatically lead to reduced yield risks. The results highlight the importance of using favourable crop rotations, sufficient N fertilizer and organic manures for maintaining system resilience and crop yield stability.

References

Macholdt J, Piepho H-P, Honermeier B, Perryman S, Macdonald A, Poulton P (2020). The effects of cropping sequence, fertilization and straw management on the yield stability of winter wheat (1986–2017) in the Broadbalk Wheat Experiment, Rothamsted, UK. The Journal of Agricultural Science 157, 65-79. https://doi.org/10.1017/S0021859620000301

J. Macholdt, M.E. Styczen, A. Macdonald, H.-P. Piepho, B. Honermeier (2020). Long-term analysis from a cropping system perspective: Yield stability, environmental adaptability, and production risk of winter barley. European Journal of Agronomy 117, 126056. https://doi.org/10.1016/j.eja.2020.126056

Impact of mineral fertilization with and without additional organic input on the temporal yield variability of winter rye – new insights from the Skierniewice (Poland) long term experiment

Marcin Studnicki[1]; Janna Macholdt[2),3]; Wojciech Stępień[4]

[1]Department of Biometry, Institute of Agriculture, Warsawa University of Life Science, Poland

[2]Institute of Agronomy and Plant Breeding I, Justus Liebig University Giessen, Germany

[3]Section of Environmental Chemistry and Physics, Department of Plant and Environmental Sciences, University of Copenhagen, Denmark

[4]Section of Agricultural Chemistry, Institute of Agriculture, Warsawa University of Life Science, Poland

marcin_studnicki@sggw.pl

Rye (*Secale cereale* L.) is a key crop grown mostly in cultivation areas under continental climate and sandy soils, as in Central Europe. This cereal can offer great advantages for improving current cropping systems in terms of the demanded sustainability and climate resilience. The expansion capability of rye need to be verified under various environmental conditions and a robust evaluation of its temporal yield variability under different agronomic management practices, such as fertilization, is needed. This is accomplished through the use of long-term field experiments (LTEs). This study aims to contribute to a better understanding of how rye yields are affected or, at best, can be stabilized by appropriate individual nutrient supply and adequate nutrient regimes. The specific objective was to identify the impact of six combinations of mineral fertilizer (CaNPK, NPK, CaPK, CaNK, CaNP, Ca), with and without additional manure, on the temporal yield variability of winter rye. For this purpose, we used rye grain yield data (1966 to 2015) coming from the LTE performed on the Experimental Station of Warsaw University of Life Science in Skierniewice, Poland (51°57'N 20°09'E). The statistical analysis was performed using a linear mixed model with restricted maximum likelihood estimation method and Shukla's stability variance approach. The results of the analyzes showed that the use of additional manure in 'non-optimal' mineral fertilizer treatments, such as Ca and CaPK, reduced the temporal yield variability of rye. In contrast, additional organic input led to more variable rye yields in 'optimal' treatments (CaNPK and NPK), compared to those with no additional manure. The best combination of a high yield level and low temporal yield variability has been found for winter rye at the mineral fertilization treatment CaNPK and NPK, both without additional organic manure. The worst combination of low and instable rye yields was observed at treatments with no mineral N (Ca and CaPK) and no additional manure supply.

Changes of acidic sandy soil properties after long-term application of different organic matters and artificial fertilizers

Marianna Makádi, Tibor József Aranyos, Ágnes Hadházy, Ibolya Demeter, Attila Tomócsik, Viktória Orosz, István Henzsel

University of Debrecen, IAREF, Research Institute of Nyíregyháza, 4400 Nyíregyháza, Westsik Vilmos utca 4-6, Hungary

makadim@gmail.com

Two long-term experiments (LTEs) are maintained in the Research Institute of Nyíregyháza, IAREF, University of Debrecen, Hungary. The oldest one, the Westsik's crop rotation experiment was established in 1929 to study i) the possible crop rotations on acidic sandy soil which are economic for farmers, ii) the effects of different organic manures and fertilizers and, iii) the effects of lupine on soil and crop yield. The experiment contains 15 crop rotations where rye, potato and lupine are sawn in 14 tree-years and 1 four-years rotations. The applied varieties have been changed several times.

The second LTE was established in 2003 for studying the effects on regular application of sewage sludge compost (SSC) on i) chemical and microbiological properties of acidic sandy soil, ii) plant yield and, iii) toxic elements content of plants. This SSC is a complex material planned for sandy soils. It contains 40% of sewage sludge, 25% of straw, 5% of rhyolite and 30% of bentonite. The compost is applied at 9, 18 and 27 t ha^{-1} doses in every 3rd years. Test plants were triticale, green pea and maize until 2017 while rye, hairy vetch with rye and maize are sawn from 2018.

The main conclusions from the LTEs:

1. Westsik's crop rotation experiment:

- NPK fertilizers decreased the soil pH significantly. This effect was moderately compensated by the added organic matter.
- The humus content of the soil increased in the order of farmyard manure, rye straw and lupine green manure.
- The soil phosphorus (P) content was increased by farmyard manure and P fertilizer. The green manure application was not affected on soil P content.
- Zinc (Zn) content of the soil was extremely increased by the regular addition of farmyard manure to the soil. (In this area the natural Zn content of soils are very low.)
- The lowest potato and rye yields were achieved in the crop rotations without or with low level (43 kg/ha/3 years) of nitrogen (N), independently of the applied organic manure form.

2. Sewage sludge compost experiment:

- Continuous improvement of soil physical, chemical and biological properties was found, with periodicity of measured results.
- Cumulative effects of SSC application were found in soil enzymes activities.
- Changes occurred in the lower (30-60 cm) soil layer at a lower level.
- Main factors of treatment differences were P_2O_5 and K_2O content of soil.
- Plant species had different reactions on SSC application.

General conclusion: adding organic matter to sandy soil improves the soil quality and fertility on a long period. Artificial fertilizers application is recommended for the higher yield.

Soil surface CO_2 efflux depending on seasonal variation and cropping management – results from agricultural LTE

Yavar Vaziritabar[1)], Feng Yan[1)], Bettina Leschhorn[1)], Christian Eckhardt[2)], Bernd Honermeier[1)]

[1)]Institute of Agronomy and Plant Breeding I, Justus Liebig University Giessen, Germany

[2)]Institute for Plant Ecology, Justus Liebig University Giessen, Germany

yavar.vaziritabar@agrar.uni-giessen.de

Soil surface CO_2 efflux (F_C) is considered to be the largest component of the ecosystem carbon balance, comprising 50 – 80 % of ecosystem respiration (Davidson et al 2002). Soil surface CO_2 efflux investigations can provide valuable information about C-dynamics in the soil.

In this study we present the results of the temporal variation of soil surface CO_2 efflux in dependence on crop management (organic and NPK fertilization) in Long-Term Experiments (LTEs). The measurements were carried out between 2019 and 2020 in two experimental sites at the University of Giessen, in Rauischholzhausen/Rau (close to Marburg, 50.45 N, 8.52 E, 225 m a.s.l., Haplic Luvisol, loamy texture) and in Giessen/Gie (70 km north of Frankfurt/M., 50.60 N, 8.65 E, 158 m a.s.l., Fluvic Gleyic Cambisol, clayey-silty texture). A portable device LI 870 CO_2/H_2O infra-red gas analyser (IRGA) combined with 8200-01S smart chamber (LI-COR Biosciences GmbH Bad Homburg) was used for the measurements. Long-term CMBR soil collars (20 cm inside diameter, 5 cm tall, 4 cm inserted into the soil) were established on the field plots (four collars per plot, 4 plots per treatment resulting in 16 measurements per treatment) before the beginning of the measurements. The study was carried out in two LTEs: (1) “BSG” in Gie (treatments: fallow, clover mulching and oat as preceding crops, measurement was done in winter wheat and winter rye one and two years after preceding crop respectively), (2) IOSDV in Rau (control, FYM, straw/green mulching, compost).

The F_C varied depending on air/soil temperature and soil moisture. In Rau (IOSDV 2019) the autumn season F_C (Sept.-Nov. 2019) (means: 2.81, 3.48, 3.81 µmol m^{-2} s^{-1} in control, FYM and straw/green mulching respectively) was only little less than summer season F_C (April-August 2020) (3.31, 3.79, 3.99 µmol m^{-2} s^{-1}) in the same treatments. Higher seasonal F_C variation was found in former investigation on grassland at the Giessen FACE experiment which is close to the LTE site Gie (Heidel et al 2015).

The long-term organic fertilization led to increase of soil respiration (F_C). So, significantly higher F_C values were observed in compost treatment of the LTE “IOSDV”, as compared to the control. FYM application and straw/green mulching also led to higher F_C mean values. A comparable F_C level was recorded during the summer season for both experiment sites, Gie and Rau. The cropping system with different preceding crops showed no clear effect on F_C values which were recorded in the fields with subsequent winter wheat and winter rye during the summer seasons of 2019 and 2020.

References

Davidson EA et al. 2002. Belowground carbon allocation in forests estimated from litterfall and IRGA-based soil respiration measurements. Agricultural and Forest Meteorology 113, 39-51.

Keidel, L., Kammann, C. Grünhage, L., Moser, G., Müller, C. 2015. Positive feedback of elevated CO_2 on soil respiration in late autumn and winter. Biogeosciences 12, 1257-1269