Meeting of the

Working Group Seed Science and Certification (GPZ/GPW)

Arbeitsgemeinschaft Saatgut- und Sortenwesen (GPZ/GPW)

&

Section IV Seeds (VDLUFA)

Fachgruppe IV Saatgut (VDLUFA)

Topic of the Scientific Seed Symposium:

“Seed Production in Times of Climate Change”
„Saatgutproduktion in Zeiten des Klimawandels“

March 9-11, 2021
Online

Book of Abstracts

Ulrike Lohwasser & Andreas Börner

PROGRAM

March 09, 2021

12:30-12:45	Andreas Börner Germany	Opening Remarks
	Chair: Andreas Börner	
12:45-13:30	Hugh W. Pritchard United Kingdom	Climate and seed functional traits
13:30-13:45	Andreas Wais Switzerland	International Seed Testing Association – The way forward in seed testing
13:45-14:00	Einav Mayzlish Gati Israel	The role of the Israel Gene Bank in genetic diversity conservation in times of climate change
14:00-14:15	Maraeva Gianella Italy	Seed longevity of maize conserved under germplasm bank conditions for up to 60 years
14:15-14:30	Filippo Guzzon Mexico	Enhancing seed conservation in tropical areas by implementing the dry chain
14:30-14:45	Ibrahim Olaleye Germany	The relationship between estimates of fluorescence lifetime and seed viability and vigour of wheat (*Triticum aestivum*)
14:45-15:00	Jayaraman Aravind Germany	Delayed fluorescence for monitoring seed deterioration in selected *Brassica* species
15:00-15:15	Erwann Arc Austria	Metabolite profiling of germinating *Brassica oleracea* seeds
15:15-15:30	Jennifer Zur Germany	The AVATARS Project – An interdisciplinary approach introducing new digital technologies for seed quality analysis in oilseed rape (*Brassics napus* L.)
15:30-15:45		**Break**
	Chair: Ilse Kranner	
15:45-16:00	Marcus Jansen Germany	Image processing for new perspectives in seed quality testing
16:00-16:15	Antje Wolff Germany	Phenotyping seeds and seedlings to objectively measure the impact of climatic conditions on seed quality, germination and vigour
16:15-16:30	Hardy Rolletschek Germany	Seed phenotyping *in vivo*: concept and developments at IPK
16:30-16:45	Lénia Rodrigues Portugal	The applicability of calorespirometry on seed phenotyping – A focus on seed resilience upon abiotic stress factors

16:45-17:00	Hannah Senior United Kingdom	Facilitating seed production through pollination control tent technology in the changing climate
17:00-17:15	Sebastian Bathiany Germany	Tailoring climate projections to the needs of agricultural stakeholders - insights from ADAPTER
17:15-17:30	Peter Zubay Hungary	Allelopathic effects of *Juglans regia* L., *Populus tremula* L. and juglone on seed germination of medicinal and aromatic plants

March 10, 2021

08:10-08:15	Manuela Nagel Germany	Opening
	Chair: Manuela Nagel	
08:15-09:00	Ilse Kranner Austria	Abiotic stress factors experienced during seed maturation affect redox signalling and seed phenotype
09:00-09:15	Manuela Nagel Germany	Longevity of seeds and the impact of the maternal environment
09:15-09:30	Olha Zadorozhna Ukraine	Seed storage of different wheat species
09:30-09:45	Hela Chikh-Rouhou Tunisia	Efficiency of three selection methods in improving onion seed yield
09:45-10:00	Annette Büttner-Mainik Switzerland	Tiger nut from seeds: From germination to tuber formation
10:00-10:15	Biljana Kiprovski, Serbia	Nutritional value of underutilised oil crop *Carthamus tinctorius* L.
10:15-10:30	Ines Fhima, Tunisia	Seed performance of Tunisian bottle gourd landraces
10:30-10:45		**Break**
	Chair: Andreas Börner	
10:45-11:00	Rouxlene Van der Merwe South Africa	Drought tolerance indices and their correlation with seed yield in vegetable-type soybean
11:00-11:15	Andrea Pagano Italy	Post-priming desiccation tolerance as a key determinant of seed priming efficiency in *Medicago truncatula*
11:15-11:30	Johann Huber Germany	Improvement of the seed quality of faba beans (*Vicia faba*) to ensure domestic seed production

11:30-11:45	Alex Kröper Germany	Identification of lentil (*Lens culinaris*) genotypes for sustainable cropping systems in temperate climate
11:45-12:00	Ulrike Lohwasser Germany	Sainfoin (*Onobrychis viciifolia* Scop., legume family) – The future star in sustainable crop cultivation strategies?
12:00-12:15	Andreas Börner Germany	Closing Remarks
12:15-14:00		**Lunch Break**
14:00-17:00		**VDLUFA Workshop**

March 11, 2021

09:00-13:00	**VDLUFA Spring Meeting**

TABLE OF CONTENTS

ABSTRACTS

ABSTRACTS

Climate and seed functional traits

H W Pritchard, E Castillo-Lorenzo, A Visscher, C Seal

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Uncertainty surrounds the prospect of sustained seed production in times of climate change, both for agricultural and wild species. Although the context is somewhat different. For crops, falling seed production under stressful conditions would have profound implications for human nutrition and health. For wild species, failure to regenerate via seed (through production, dispersal and germination) means an increasingly unstable landscape and the loss of ecosystem services. Notwithstanding these differences, the desire of the crop technologist and conservation biologist is the same; access to seed lots that are fit-for-purpose. In other words, the seeds have the right functional traits for the intended environment. But how do we know if this is the case? Over many years we have been characterising seed functional traits in a wide range of species, with different growth habits and from diverse environments. It has been possible to characterise the environmental limits to and kinetics of germination performance and comprehend how they are affected by the natural environment. In making comparisons between wild relatives and mainstream crops, one question that has arisen is 'might crop seeds be relatively dysfunctional due to being produced in a benign, managed environment?' Beyond physiological comparisons amongst species, the greatly increased access to reference genomes means that comparative genomics for wild species is becoming a reality. Consequently, the opportunities for cross-talk between disparate plant science communities can only increase. It is hoped that one outcome of such largesse is a deeper understanding of seed functional traits and climate.

International Seed Testing Association – The Way Forward in Seed Testing

A Wais

ISTA Secretary General, CH-8303 Bassersdorf, Switzerland

Uniformity in seed testing is the mission of the International Seed Testing Association (ISTA). Founded in 1924, with the aim to develop and publish standard procedures in the field of seed testing, ISTA is inextricably linked with the history of seed testing. With member laboratories in over 80 countries/distinct economies worldwide, ISTA membership is truly a global network. In Austria, Germany and Switzerland ISTA counts 19 member laboratories and 32 personal or associate members, making the VDLUFA area one of the key member countries of ISTA.

Seed is starting material for life. Seed quality is obligatory to achieve this. And seed testing is the way to proof quality.

ISTA is working up to a new century of its existence. For this we are preparing with a number of projects ling attracting younger people to seed testing by a project called Young@ISTA, the introduction of electronic ISTA Certificates, up-to-date pest lists to address seed health issues, project funds for new techniques and matters to make ISTA fit-for-future.

The role of the Israel gene bank in genetic diversity conservation in times of climate change

E Mayzlish Gati, S Golan, D Lifshitz, A Zinger, T Farag, O Cohen, L Hagai

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The Israel Gene Bank (IGB) of the Agricultural Research Organization is the national center in Israel to preserve the genetic resources of regional vegetation and to provide an available source of plant material for applied research.

Israel contains some of the richest variety of plant species found in the world. The region is recognized as a center of genetic diversity and is characterized by the abundant presence of crop wild relatives (CWR) of grains (wheat, barley, oats), legumes (peas, lentils, chickpeas), fruit trees (plum, pear, fig), vegetables (garlic, carrot, cabbage), aromatic plants (sage, fennel, hyssop), and productive plants (flax, clover, alfalfa). Currently, the IGB collection holds 95% of the 370 different CWR of Israel.

Moreover, the IGB holds a unique collection of local landraces that have been collected since the beginning of the 20th century. These were deposited in the IGB and gene banks worldwide, and are now exported back to Israel and provide Israeli and international researchers with access to important pools of traits and genes for better research and breeding to tackle climate change and growing food demand.

Cultivating new agricultural varieties able to withstand extreme climactic change is a challenge that requires focus beyond crop quantity or quality. Plant breeders today must emphasize resilience to extreme temperatures, short and intense rainfall regimes, and the ever-changing diseases caused by climate change. Wild plants and landraces are vast repositories of genetic diversity for crop improvement. Their genetic variety can improve the adaptability of crops to current and future environmental challenges.

In my talk I will discuss the IGB's conservation agenda for our different collections as an important source for research and breeding toward climate changes.

Seed longevity of maize conserved under germplasm bank conditions for up to 60 years

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In a scenario of global climate change and increasing human population, long-term seed conservation is of paramount importance for plant genetic resources preservation, which will ensure the characterization and use of useful genetic traits in breeding programs, now and into the future. However, little is known about the longevity profiles of seed accessions conserved in germplasm banks, especially at intra-specific levels: this is partly due to the lack of viability data and the relatively short lifespan of seed banks around the world.

In order to explore the longevity profile of maize (*Zea mays* subsp. *mays*), one of the major crops for global agriculture, we tested the decline in viability, using original as well as historical monitoring data, in one thousand diverse seed accessions. These were conserved for an average of 48 years in the CIMMYT germplasm bank, the largest maize seedbank in the world, under two cold storage conditions: an active (-3 °C; intended for seed distribution) and a base conservation chamber (-15 °C; for long-term conservation). The current project represents one of the largest seed longevity experiments ever performed.

Seed lots stored in the active chamber had a generally lower and more variable seed germination, averaging 81.4%, as compared to the seed lots conserved in the base chamber, averaging 92.1%. The same accessions conserved in both chambers showed a higher decline in viability when conserved under active chamber conditions. A significant difference was detected in seed germination and longevity estimates (e.g. p_{85}/p_{50}) among accessions, and this difference was strongly correlated with grain type, among all of the seed traits considered.

The more rapid decline in viability detected in the active chamber suggests that this conservation approach might be counterproductive for seed conservation and that base conditions should be applied both for distribution and long-term conservation purposes. The significant differences in longevity among accessions underscores the likelihood that different viability monitoring and regeneration intervals might need to be applied, based on identified types of accessions, rather than wholly at the species level. Several additional technical improvements to enhance seed conservation of maize diversity are also described.

Enhancing seed conservation in tropical areas by implementing the dry chain

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Seed conservation in tropical areas is affected adversely by high relative humidity that promotes insect and fungal infestations and leads to rapid losses in seed viability. In addition, unreliable power supplies often do not allow the use of dehumidification or refrigeration systems. We tested the dry chain, i.e., initial seed drying with a reusable desiccant (zeolite beads), followed by storage in hermetic containers, in Guatemala, Mexico and India. In Guatemala, we compared the dry chain with local maize seed conservation methodologies in three farming communities. Seeds conserved using the dry chain at ambient temperatures maintained higher seed viability (>80%) and reduced fungal and insect infestations (<3%) throughout six months when compared to the other treatments. The use of drying beads coupled with a recirculating ventilator in a cabinet was tested in the tropical research station of CIMMYT (Mexico). This lowered the moisture content (MC) of 21 accessions of fresh maize seeds to <9% in 4 days without added heat. The same MC was achieved in three weeks in the ventilated drying room of the CIMMYT seedbank (standard methodology). No differences in potential seed longevity (estimated through controlled ageing tests) were observed between the two drying treatments. In India, mung bean seeds dried using desiccants had higher germination percentages and seedling vigor as well as lower electrical conductivity and fungal infestation compared to other treatments after nine months of storage. In addition, seeds inoculated with bruchid beetles and stored with desiccants in hermetic containers had much less damage, oviposition, and insect respiratory activity compared to other treatments. These experiments demonstrated that the dry chain is a versatile and effective system that can be applied across crop species and at different scales to enhance seed conservation and improve seed security for farmers in tropical areas.

The relationship between estimates of fluorescence lifetime and seed viability and vigour of wheat (*Triticum aestivum*)

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Seed genebanks are plant genetic resource centres established to conserve germplasm ex-situ, where viability is routinely estimated used to determine seed shelf-life before and during storage under low temperature and moisture conditions. Traditionally, germination testing is the process used to determine seed viability practised in all genebanks. However, it is a destructive and time-consuming process putting valuable germplasm at risk. The reason for this study is to find the possibility of a rapid and non-destructive method of seed viability testing using delayed luminescence.

“Time-Correlated Single Photon Counting" technique was used to measure delayed luminescence and compare it with the destructive seed viability testing methods. ‘KWS Sharki’ spring wheat seeds (*Triticum aestivum*) were aged artificially at 48 °C under 40% and 60% RH representing slow and rapid ageing for different time periods to generate samples with five distinct germination percentages as predicted by seed viability equation (100, 80, 50, 30 and 10%). Each sample was then further equilibrated to five different moisture levels (80%, 60%, 40%, 20% and 11.2%). Actual seed moisture content was determined by high constant oven temperature method. Decay counts were measured on the milled and intact seeds, using Horiba DeltaPro Fluorimeter at both fluorescence (10 ns) and phosphorescence time scales (340 μs) after excitation with a pulsed laser. Fluorescence lifetime was estimated by EzTime software by fitting a three exponential decay function accounting for confounding with instrument response function. Seven days of germination testing in a 20 °C growing chamber with 24 hours daily count was done to compare and determine the correlation of viability with the delayed luminescence measurements.

Significant differences were observed in seed vigour and seedling emergence across all treatments after germination. Also, fluorescence and phosphorescence measurement proved to be a non-destructive, non-invasive and faster technique to assay seed quality than the germination test.

Delayed fluorescence for monitoring seed deterioration in selected *Brassica* species

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Plant genetic resources are largely conserved under ex situ conditions in the form of seeds. Such seed genebanks conserve seed material under low temperature and moisture storage environments. One of the key genebank activities is to determine the quality of seed prior to storage as well as at regular intervals. This is traditionally done by seed viability or germination testing, which is resource intensive, time consuming and destructive leading to loss of precious seed material. Hence there is an ongoing exploration for alternative non-destructive and high-throughput techniques to determine seed viability and in turn seed ageing. Apart from seed genebanks such methods can aid seed industry to provide good quality seeds for agriculture.

Delayed fluorescence is one such promising technique which was explored to assess seed viability in *Brassica oleracea*, *B. napus* and *B. carinata*. Seed samples of selected accessions conserved under both ambient and genebank long-term storage conditions for more than ten years were used for the study. They were excited with a pulsed laser source and the excitation fluorescence was measured with a sensitive photomultiplier tube. Fluorescence decay lifetime as well as spectra were estimated for analysis. The seed viability of the samples was tested by recording cumulative seed germination at one day intervals indicated by radicle emergence of 1 mm for seven days in a growth chamber maintained at 30 °C with light for 8 hours and at 20 °C for 16 hours of darkness. Cumulative seed germination counts were fitted with the four-parameter hill function to estimate parameters corresponding to germination percentage, rate, and time. Seed stored under ambient storage showed greater degree of deterioration than those stored under long term storage conditions. Preliminary results showed that the fluorescence data could differentiate samples of low and high seed deterioration with good degree of accuracy.

Metabolite profiling of germinating *Brassica oleracea* seeds

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Production of high-quality seeds is key to sustained food production. However, environmental stress factors impacting on plants can affect seed yield and also influence seed germination performance. Seed germination comprises a sequence of molecular and physiological events initiated upon seed imbibition, leading to drastic changes in gene expression and a sequential remodelling of the proteome and the metabolome. We characterised seed germination in *Brassica oleracea*, a crop relative of the model plant *Arabidopsis thaliana*, using seeds produced under drought or suboptimal temperature – stress factors predicated to occur more frequently in the future due to climate change. Mass spectrometry-based metabolite profiling unravelled metabolic changes occurring during seed germination. Taking advantage of two *B. oleracea* genotypes with almost identical genetic background, but differing in germination vigour, allowed gaining new insights into molecular events underpinning differences in seed vigour, with a critical role of the tricarboxylic acid cycle.

The AVATARS Project – an interdisciplinary approach introducing new digital technologies for seed quality analysis in oilseed rape (*Brassica napus* L.)

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AVATARS is a flagship project in the field of plant breeding facing the challenges of integrating extensive and diverse multimodal time-resolved data sets using a virtual and augmented reality (VR/AR) environment in combination with deep learning technology. The integration through a VR/AR environment will not only allow the interactive exploration of highly complex data in research and breeding application but also impact education by providing an innovative teaching and learning experience.

Scientifically, AVATARS will focus on seed formation of *Brassica napus*. We will develop a time-resolved virtual 3D seed model based on high-resolution MRI, high throughput X-ray CT and histological data. The 3D seed model will be transferred into a VR/AR environment allowing to interactively experience transcriptome, proteome, and metabolome data.

Furthermore, the virtual 3D seed model will include epigenetic information in a selection of contrasting genotypes grown in controlled conditions, either beneficial or detrimental to seed formation. The integration of genetic and environmental factors allows determining their effect on seed quality traits.

Novel deep learning algorithms gathering information from 2D and 3D seed phenotype by hyperspectral imaging and computed tomography, as well as phenotypic, environmental/climatic, and genotypic data collected in field trials of up to 400 breeding lines will support the prediction of agronomic important traits such as seed germination and vigour.

The modelling of these big data will ultimately be centered towards each genotype's individual germination behavior after accelerated and natural ageing. To demonstrate the *single seed to single seedling* analysis pipeline and understanding the challenge of introducing non-invasive new digital technologies for seed quality analysis are the focus topics of the presentation.

Image processing for new perspectives in seed quality testing

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Seed assessments at various levels traditionally rely on visual inspections, but optical technologies increasingly take over rating tasks. While seed counting with computer vision is already established, optical inspections of germination processes, seedling quality, or seed purity are gaining importance. The implication of machine learning enables training the image processing algorithms in a way that the dedicatedly recognize features that are important for specific ratings. Thereby, it becomes possible to move automatic imaging-based inspection of seeds and seedlings closer to the demand of the rating experts. Beyond application-specific image processing, key advantages of such methods are consistent documentation of the samples by storing the original images and measuring options for all recognized items. This measuring options enable determining the size of each and every detected seed, seedling, root, shoot, or leaf can be measured for a range of parameters, including length, width, area, or information on colors and morphology.

Phenotyping seeds and seedlings to objectively measure the impact of climatic conditions on seed quality, germination and vigour

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Unusual climate events such as draughts, heavy rainfall, hail, sudden cold periods and others signify severe implications for seed quality and consequently germination capacity and vigour of plants and exert a high burden on agriculture, horticulture, forestry, ornamental plant production and other sectors dependent on seed quality and plant growth. As only fully developed and ripe seeds have the potential to produce high performing plants with high yield in bio mass or good seed yield, optimisation of seed quality is the precondition for a sustainable food production and afforestation.

The phenoTest is a high-throughput phenotyping system based on 3D computer tomography, which longitudinally and quantitatively monitors individual plant development from seed to seedling under laboratory conditions by automated image analysis of 3D- image data. It thus provides objective, reproducible and fully automated digital measurements of all relevant plant organs over time.

This technology can be highly effectively applied to capture and evaluate the effect of abiotic stress on the integrity of seeds and the germination behaviour, vigour and quality of the emerging plants. Data on the interrelation of environmental conditions and seed quality and plant development can inform basic research about the effect of genotype versus environment on phenotypic traits of seeds and seedlings/young plants.

This allows optimized seed breeding of more resistant plants as a long-term reaction to the climatic change.

For the practical work of seed processors and germination labs the phenoTest provides not only data such as germination capacity and number of abnormal seedlings but as well a complete and detailed list of the phenotypic properties of each single seedling and therefore a quantification of the plant quality and vigour as well as a documentation as image-files. Data from the objective measurement help seed processors to control selective and individual seed processing for only high-performing seeds.

Seed phenotyping *in vivo*: concept and developments at IPK

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Beside genotyping, information on the phenotype of mature seeds is of increasing relevance in the management of plant genetic resources as well as breeding programs. Over the last decade, we established an analytical pipeline for comprehensive phenotyping of living seed. This pipeline is based on Light Microscopy (LM), Near Infrared Spectroscopy (NIRS), Nuclear Magnetic Resonance (NMR) and sensor technology. LM, NIRS and NMR enable high throughput analysis of seed shape and composition, and NMR imaging gives rise to spatially resolved three-dimensional seed models. This allows to detect both characteristic features and irregularities in internal seed structure. A high-throughput procedure for testing seed viability and germination, based on respiration assays, is applied (as alternative to the standard practice of seed germination tests defined by ISTA protocols). Such data provide the base for defining novel seed traits, not accessible so far. In our presentation, we provide examples of the outcome of this seed phenotyping platform and its use in current research and breeding programs.

The applicability of calorespirometry on seed phenotyping – a focus on seed resilience upon abiotic stress factors

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To support the needs imposed by the continuous increase in human population and by climatic and edaphic changes, agronomical strategies based on more sustainable practices have been developed. Several breeding programs have been implemented focused on the development of more resilient cultivars. A strong focus has been given to seed sector, in order to develop genotypes able to produce more vigorous seeds with higher plasticity upon environmental constraints and high germination rates.

The establishment of a phenotyping tool able to assist breeding programs in the selection of high-quality seeds has an obvious interest to seed breeders companies, crop producers and consumers. Calorespirometry, a technique that simultaneously measures heat and CO_2 rates, has been proposed as a screening tool to assess metabolic and respiratory changes associated with cell reprogramming events.

The applicability of the technique has been demonstrated in different biological systems, and currently, in the frame of the European Research project LIVESEED (https://www.liveseed.eu/), calorespirometry is being developed by the UÉvora to be used as a phenotyping tool to assist breeding programs focused on the selection of genotypes with increased resilience upon environmental stresses. In particular, it has demonstrated to be a valuable phenotyping tool to assess seed viability without requiring to grow plants under different environmental temperatures.

In this work, different pea cultivars were screened at seed level with this technique with the aim of identifying of the most resilient genotypes upon temperature stress. Alternative pathway inhibitors were additionally used during the procedure to determine the involvement of this respiratory pathway in seed germination efficiency. The results obtained so far show that calorespirometry is a useful screening tool to assess seed viability and to discriminate between different cultivars based on alternative respiration efficiency. Moreover, it provided an important indication about the involvement of alternative respiratory on seed germination efficiency.

This work was supported by the EU project LIVESEED - Improve performance of organic agriculture by boosting organic seed and plant breeding efforts across Europe funded by the European Union's HORIZON 2020 research and innovation programme under the Grant Agreement no 727230, and by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 17.00090; and by National Funds through FCT under the Project UIDB/05183/2020. Authors are very thankful to IIFA for the fellowship given to Lénia Rodrigues. The opinions expressed and arguments employed herein do not necessarily reflect the official views of the EC and the Swiss government. Neither the European Commission/SERI nor any person acting behalf of the Commission/SERI is responsible for the use which might be made of the information provided on this website.

Facilitating seed production through pollination control tent technology in the changing climate

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Changing climate with elevated temperature and water stress is impacting the reproductive phase of plants to reduce seed yield and quality. Moving seed production sites, varying sowing dates and the breeding of short duration and climate-adapted varieties are some options but may not be available to all seed growers. We propose unique but simple alternatives of using synthetic fabrics pollination control systems providing ambient micro-climatic conditions for increased and healthy seed production with assured genetic identity. We found in many crops that nonwoven fabric pollination control bags (PCB) result in higher hybrid seed output on a small scale. The pollination control tents (PCT), on the other hand, provide larger scale seed production options. Recent advances in PCT technology make it feasible to expand tents to larger areas in multiples of 1.5 x 3m footprints retaining their robustness for winds up to 100 kph. In tall fescue, using two nonwoven fabric tents (DWB 10 and DWB24) we obtained significantly higher seed yield over open pollinated control (DWB10 gave 37% higher seed yield). The average temperature and humidity within tents were more conducive than outside. Further adaptations in the PCT technology involve provision of fans or mesh covers within the same framework creating more options; to protect against zoophilous pollination; to protect against pests, birds and high winds; to create greater flexibility. Mini tents of three nonwoven materials covering single plants of 1TM37 male sterile in sugar beet exhibited complete pollen proofing despite high pollen presence in the outside environment. The greater porosity without pollen contamination with new fabrics provided more aeration for the ambient conditions for healthy and higher seed production. This technology is undergoing further tests with a number of plant types in the US, UK, Canada and France including anemophilous and zoophilous crops.

Tailoring climate projections to the needs of agricultural stakeholders - insights from ADAPTER

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Agriculture is among the sectors that are most vulnerable to extreme weather conditions and climate change. In Germany, the subsequent dry and hot summers 2018, 2019, and 2020 have brought this into the focus of public attention. Agricultural actors like farmers, advisors or companies are concerned with such interannual variability and extremes. Yet, it often remains unclear what long-term adaptation options are most suitable in the context of climate change, mainly because climate projections have uncertainties and are usually not tailored to meet requirements, measures and scales of the individual practitioners. In the ADAPTER project, we explore regional and local change on the weather- and climate-related time scales and together with stakeholders (administration, plant breeders, educators, agricultural advisors), we co-design tailored climate change indices and usable products.

In this contribution, we first demonstrate which aspects of climate change are most important for our stakeholders regarding the breeding of new crops and identifying ideal testing areas and future regions of cultivation. Second, we present a comprehensive data analysis based on weather observations, model analyses of past weather, and 85 regional climate simulations, and show what changes can be expected in the next decades.

We identify and analyse practically relevant climate indices, that are tailored to specific soil-climate zones in Germany and to critical stages of plant development during the year.

The indices capture aspects of climate change like increasing temperature variability, the increasing occurrence of combined heat and drought, and changes in the potential accessibility of soils.

Based on the results, we discuss to what extent recent developments are in line with our expectations of future climate change, and present our freely available ADAPTER "product platform" devised to help agricultural stakeholders adapt to climate change.

Allelopathic effects of *Juglans regia* L., *Populus tremula* L. and juglone on seed germination of medicinal and aromatic plants

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Agroforestry systems are characterized by a broad range of environmental benefits i.e. maintaining ecosystem-services and biodiversity, conservation of soil, sequestering carbon and supporting soil food web, pollination and biological control. However, current knowledge on potential negative interspecific interactions, such as competition through allelopathy is inadequate. The decrease in soil fertility, the increasingly rhapsodic distribution of precipitation, and the special metabolism and cultivation of medicinal and aromatic plants are all harbingers of medicinal-agroforestry systems. The authors aimed to discover the allelopathic effects of *Juglans regia* L. and *Populus tremula* L. on germination of medicinal and aromatic plants cultivated in a temperate zone. Accordingly, an in vitro germination trial was conducted with leachates of these trees and two juglone concentrations. These allelopathic effects were evaluated for germination vigour, germination rate, and total fresh weight of seedlings of twelve different species. A pronounced species specificity was observed in tolerance of seeds and seedlings to the allelopathic effect of *Populus* and *Juglans*. In four of the species studied, the allelopathic effect may inhibit germination, but only initially. Poppy and angelica proved to be the most sensitive to the treatments. The following species had relative tolerance to the allelochemicals, so further research under natural conditions is suggested for: *Althea officinalis* L. (9.34±5.04 - 68.66±13.62 GR%), *Anethum graveolens* L. (12.00±2.00 - 100.00±6.12 GR%), *Cannabis sativa* L. (72.66±9.02 - 91.34±1.16 GR%), *Dracocephalum moldavica* L. (38.00±2.00 - 80.00±17.44 GR%), *Linum usitatissimum* L. (44.66±2.00 - 58.00±3.46 GR%), and *Satureja hortensis* L. (52.00±28.22 - 82.00±8.00 GR%). The aim would be to introduce them into temperate zone medicinal-agroforestry systems.

Abiotic stress factors experienced during seed maturation affect redox signalling and seed phenotype

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Seeds are key to agricultural productivity, food security and plant conservation. However, the role the environment plays during seed development, and its downstream effects on seed quality are far from understood. Here we report on the effects of suboptimal temperatures and drought experienced by the mother plant on seed quality, with a focus on redox signalling. Plants of *Arabidopsis thaliana*, *Brassica oleracea*, *Hordeum vulgare* and *Helianthus annuus* plants were subjected to the above-mentioned abiotic stress factors, which are predicted to occur with increasing frequency in climate change scenarios. Amongst other effects, elevated temperatures led to reduced thermodormancy in *A. thaliana* and *H. vulgare*, and affected mean seed size and quality in *A. thaliana* and *B. oleracea*. In all species, the abiotic stress factors experienced by the mother plants plant clearly affected the concentrations and redox state of antioxidants such as glutathione (γ-glutamyl-cysteinyl-glycine), concentrations of tocochromanols and protein carbonylation, thereby resetting the seeds' redox environment as well as reprogramming their genomes. Gene ontology analysis confirmed that pathways involved in redox signalling were affected by the abiotic stress factors experienced during seed development, with downstream regulation of important seed quality traits such as seed viability, dormancy and longevity.

Longevity of seeds and the impact of the maternal environment

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Long-term storage of orthodox, desiccation-tolerant seeds is important to conserve plant genetic resources for research, breeding and future applications. The Federal *Ex situ* Genebank for agricultural and horticultural plants in Gatersleben, Germany, preserves more than 150,000 accessions of about 3,000 different species. To assess the viability status of the different collections and the necessity of seed regeneration, more than 405,000 germination tests have been conducted since 1976. The current study aims to use the results of the germination tests and to predict seed longevity for important crop species such as barley (*Hordeum vulgare*), oilseed rape (*Brassica napus*) and sugar beet (*Beta vulgaris*). The further analysis showed that growth conditions during seed development affected significantly seed quality. Therefore, plants of two barley genotypes were subjected to drought (23/15 °C, 15% field capacity) and elevated temperatures (28/25 °C). In both genotypes, TSW was strongly reduced by drought. Elevated temperatures showed significant effects only for the genotype HOR 4710. This genotype developed smaller plants and spikes and produced smaller and less seeds. Seeds of HOR 4710 were also thermo-dormant when they were grown at 20 °C. In conclusion, seed vigour can be affected by maternal environment during seed development; thus, can have consequence on the storability of plant genetic resources. Therefore, seedbanks must apply best agricultural practice to develop seeds under optimum environmental conditions.

Seed storage of different wheat species

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Wheat seeds according to storage experience have medium longevity. Data on seed storage of different species wheat are scarce. Some seed longevity variation of different wheat species in model storage conditions is known. Fifteen thousand wheat accessions are stored in genebank of Ukraine under controlled conditions. Among them, more than 12500 accessions are bread wheat (*Triticum aestivum*), more than 1700 accessions are durum wheat (*T. durum*) and about 500 accessions belong to other wheat species (*T. monococcum*, *T. dicoccum*, *T. spelta*, *T. persicum*, *T. turgidum*, *T. aethiopicum*, *T. ispahanicum*, *T. sphaerococcum*, *T. urartu*, *T.araraticum*, *T.compactum*, *T.polonicum*, *T.timopheevii* and other). Seeds for storage are dried to recommended moisture content and stored in three blocks: ones with unregulated temperature, 4 °C, minus 20 °C. The average annual temperature in the block with unregulated temperature located in the eastern forest-steppe of Ukraine is 9 °C. The vast majority of wheat accessions are now at minus 20 °C with a seed moisture content of 5-7%. More than 15 years ago, wheat seeds were laid mainly in storage at unregulated temperature or 4 °C. The aim of our work was to determine the longevity of wheat seeds accessions of different species stored at unregulated temperature and at 4 °C for 10 years and longer.

Analysis of *T. aestivum*, *T. durum*, *T. monococcum*, *T. dicoccum*, *T. spelta*, *T. persicum*, *T. turgidum* seed longevity grown in 1997 and 2005 shown original seed germinability unchanged for the most for seeds with 5-7% moisture content at average annual temperature 9 °C. At 4 °C was observed better seed longevity. The best longevity of wheat seeds is observed at more arid conditions of plant cultivation with hydrothermal coefficient < 1.

Efficiency of three selection methods in improving onion seed yield

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Onion (*Allium cepa* L.) is one of the most important vegetable crops worldwide and is of great interest because of its nutritional and medicinal properties. Onion is allogamous crop, protandrous with anthers shedding pollen before the stigma of the flower becomes receptive. It is an entomophilous species that requires insect pollinators specially honey bee to ensure appropriate seed production. Although self-pollination between flowers of the same umbel is frequent. Being highly cross-pollinated with 2 years per generation life cycle and thermo-sensitive crop, breeding efforts in this crop are minimal.

With the impending climate change, it is predicted that like all other crops, onion cultivation will also suffer the consequences of various biotic and abiotic stresses. To evolve against these stresses, quality improvement is of principal concern. The purpose of this research is to evaluate the efficiency of three breeding methodologies (recurrent selection, pedigree selection and synthetic populations) in improving sustainable seed production.

Eight onion lines (red, white and yellow) were developed by Dr. Sta-Baba during 2010-2017 based on open pollination by developing lines under natural pollination conditions or based on self-pollination by developing lines under insect proof cages. The onion lines were then evaluated in the Sahline Experimental Station during the cropping season 2018-2019. The traits evaluated were: days to flowering, number of umbels, seed yield per umbel, seed yield per plant, and 1000-seed weight.

The results evidenced significant differences among onion lines and among breeding methods for the evaluated traits. Synthetic populations had the highest seed yield. The recurrent selection lines showed higher seed yield performance than pedigree selection lines. Multivariate analysis indicated that the variation among onion lines developed by different methods is due mainly to variation in days to flowering, and seed yield. Open pollinated lines, were found to be more appropriate to increase the onion seed yield.

Tiger nut from seeds: From germination to tuber formation

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Tiger nut, *Cyperus esculentus*, behaves as a weed in almost all temperate, tropical, and subtropical regions of the world. In Switzerland, the plant has been included in the black list of invasive neophytes due to its potential to spread. Once established, tiger nut becomes very difficult to eradicate. The importance of seeds in the spread of *Cyperus esculentus* was considered irrelevant in temperate climates for a long time. However, based on observations by attentive farmers, Agroscope started to investigate this aspect of tiger nut dispersal in more detail in 2014 (Keller et al., 2015; 2018).

We were able to show that seeds of *Cyperus esculentus* from different regions of Switzerland germinate well on different substrates: on agar, in standardized germination tests on paper, and in the greenhouse in soil. A total of 185 seed samples from crosses of different locations and from inbred lines were tested for their germination ability under laboratory conditions. As expected, the cross lines produced significantly more seeds overall than the inbred lines. About three quarters of all samples showed a germination capacity of at least 50 %. The seeds that did not germinate were for the most part not dead but dormant.

Furthermore, field trials confirmed that seeds of *Cyperus esculentus* have good germination potential not only under optimal conditions in the laboratory, but also under field conditions when there is little competition. Within one vegetation period, the seedlings establish plants that form tiger nuts. With the formation of tubers, the tiger nut population is secured at the newly colonized site. In order to stop the further spread of tiger nut, both the formation of tubers and the formation of seeds must be prevented. Natural seed formation also leads to recombination of the genetic material. This could lead to new clones that are more vital and better adapted to the habitat, and which may be even more difficult to control. This should be avoided as far as possible.

Nutritional value of underutilised oil crop *Carthamus tinctorius* L.

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Seeds of seven different genotypes of underutilised oil crop *Carthamus tinctorius* L. (Asteraceae) were analysed for their protein, oil, fatty acids, tocopherols and total phenolics contents, with a view to test their diversity and potential as an alternative source of these valuable compounds. Seeds of tested safflower genotypes had total protein content from 11.5 to 16.0%, while total oil content were from 16.8 to 24.5% of dry matter, on average. Two main unsaturated fatty acids in safflower seeds, oleic and linoleic acids, represent approximately 90% of the total fatty acid content. Linoleic acid was dominant fatty acid in all genotypes (61.2-80.2%), while oleic acid was in a negative correlation with linolenic acid content and was in a range from 9.6 to 29.5%. The amount of saturated fatty acids ranged from 5.5 to 6.05% for palmitic, and 2.1 to 3.5% for stearic acid. Safflower seed is a source of α-tocopherol and its amount ranged from 358.8 to 461.8 mg/L of oil. The content of total phenolics ranged from 4.0 to 6.0 mg of gallic acid equivalents/g. This comprehensive screening of valuable chemical compounds of safflower seeds shows the importance of this alternative oil seed crop as a good source of important nutrients and bioactive constituents.

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Seed performance of Tunisian bottle gourd landraces

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Bottle gourd (*Lagenaria siceraria* (Molina) Standl.) also known as calabash gourd or white flowered gourd, is a member of the Cucurbitaceae family. It has been observed to grow well in temperate, tropical and sub-tropical climates as well as low lying areas of arid to semi-arid climates. The seeds of the crop have been reported to contain high levels of oil that is comparable to those of sunflower and grape oil. Unfortunately, it is a neglected underutilized species. Bottle gourd has been used for decades as a rootstock for watermelon to promote the root system under stressful conditions of water deficit and salinity, low temperature as well as root borne pathogens. These make *L. siceraria* a useful crop to include in climate change adaption strategies for agronomy.

Selection of right material for planting is important for improved seed yield and quality. The objective of this study was to evaluate seed morphology of Tunisian bottle gourd landraces and its effect on seed quality (germination, vigour and early establishment of seedlings). These landraces were also evaluated for their resistance to the soil-born pathogen *Fusarium oxysporum* f. sp. *melonis* (FOM). Seeds of each landrace were measured for the following morphological traits: seed weight, seed length, and seed width. Seed germination, length and width of the cotyledon, root length and root fresh weights of the seedlings were also evaluated. The results showed that all the evaluated traits were significantly different, the relationship among traits involving seeds, cotyledons and fruit were reported. Indeed, the highest correlation was found between seed length, seed germination and cotyledon length. It is concluded that *L. siceraria* seed morphology could be a useful trait for selection of vigorous plant material. All the evaluated landraces were resistant to FOM and could be utilized as resistant rootstocks.

Drought tolerance indices and their correlation with seed yield in vegetable-type soybean

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The need for a highly nutritive crop that can help alleviate malnutrition among peri-urban communities in South Africa has led to the establishment of vegetable-type soybean as a crop in the country. With the introduction of a new crop, multi-environment trials are necessary in order to identify promising cultivars for production by farmers as well as to identify cultivars that show adaptation to various production areas. Thus, there is a need to evaluate the introduced vegetable-type soybean cultivars in terms of yield-based drought tolerance indices and to identify cultivars that would perform well in areas that are inclined to drought stress conditions. In total, 15 genotypes were subjected to two water treatments, a water-limited-induced stress (WLIS) treatment and a non-WLIS treatment, using controlled irrigation throughout the growth cycle. The field trial was laid out in a factorial design with three replications. At maturity, data on seed yield were recorded and subjected to analysis of variance. Nine yield-based tolerance indices were calculated and respectively used in correlations, principal components and cluster analyses. Highly significant genotype, treatment and interaction effects were observed indicating variation in terms of cultivars and their response to the water treatments. Highly significant correlations were observed among the tolerance indices indicating that they could be used to discriminate cultivars showing high yield potential respectively under both conditions, WLIS and non-WLIS conditions. Cultivars were further separated according to their tolerance and yield stability. AGS354 was the best yielding cultivar under both water treatments, UVE7 and UVE14 were the most tolerant and stable of all cultivars while PAN1729 and UVE8 were identified as good performers under non-WLIS conditions. UVE17 was most susceptible and unstable to WLIS. The tolerance indices together with multivariate analyses were effective in differentiating tolerant and stable vegetable-type soybean cultivars that could be promoted for production.

Post-priming desiccation tolerance as a key determinant of seed priming efficiency in *Medicago truncatula*

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Seed quality is crucial for the vast majority of farming systems. A variety of seed priming techniques are continuously optimized to ensure the high germination rates and the efficient seedling establishment required for agricultural productivity. Priming protocols implement physical and chemical treatments aimed to pre-activate seed metabolism and stress response during imbibition, thus improving post-priming germination performances. The dehydration phase following priming treatments (dry-back) represents a critical variable in priming protocols, since prolonged imbibition (over-priming) impairs seed desiccation tolerance, compromising seed germination and seedling development. The current priming protocols generally optimize dehydration timing empirically to avoid over-priming. Hence, a better understanding of the dynamics underlying desiccation tolerance represents a promising route to design efficient and cost-effective priming protocols.

In the present work, three strategies of seed priming (1) hydropriming, (2) hormopriming with the phytohormone kinetin, and (3) chemopriming with the polyamine spermidine, were screened in the model legume *Medicago truncatula*. Biometric analyses were used to assess the effects of the priming protocols, highlighting contrasting responses in terms of germination performances and seedling development. Priming and over-priming conditions were defined to explore the role of desiccation tolerance in seed priming efficiency. The biometric data were integrated with analyses of ROS (Reactive Oxygen Species) production, suggesting possible applications to monitor priming progression. The present results aim to expand the current knowledge of desiccation tolerance in the context of seed priming, with potential impacts on agricultural productivity.

Improvement of the seed quality of faba beans (*Vicia faba*) to ensure domestic seed production

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Faba beans (*Vicia faba*) are one of the most important grain legumes with a long history in Germany and other European countries. Its crop area is increasing due to the expansion of organic farming and the higher importance of the crop rotation effect because of less available pesticides for plant protection. However, the provision of local produced faba bean seeds is more and more endangered because the lawful minimum germination ability of 80 % is becoming more and more difficult to reach. Besides the high sensibility of faba beans during harvesting the broad bean beetle (*Bruchus rufimanus*) has the biggest impact on the germination ability. The females lay their eggs on the bean pods and the freshly hatched larvae carve themselves into the developing beans. The adult beetles either leave the beans after harvest or overwinter in the beans and leave in spring.

In this research project a three years field trial on three different sites in Germany is performed to elaborate different control strategies against the broad bean beetle. In 2019 and 2020 the organic and conventional field trials were cultivated in three regions with different climatic conditions: Upper Bavaria, Schleswig-Holstein, Saxonia in 2019 and Lower Franconia in 2020. Different strategies to control the broad bean beetle and the possible impact on the germination ability of the seeds were tested for their effectiveness. In the organic field trials neem oil and the ichneumon species *Lariophagus distinguendus* as a natural enemy of *Bruchus rufimanus* are applied whereas in the conventional field trials the application of an officially approved insecticide and a late seeding time are used. None of the implemented control measures was able to ensure germination abilities over the legally defined value of 80 % in both organic and conventional field trials after two years. The results of the two years field trials are presented.

Identification of lentil (*Lens culinaris*) genotypes for sustainable cropping systems in temperate climate

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Lentil cultivation plays a minor role in Germany at present. Due to a growing preference for vegetarian or vegan food and the consumers' awareness of regional food production, the demand for locally grown lentils is increasing. Lentil plants have a comparatively short growing season of four months and show a high tolerance to drought periods. Therefore, they hold great potential for cultivation under conditions of advancing climate change. To date, lentil is an underutilized crop in Germany, and there are no modern varieties available which are adapted to the current growing conditions and which can cope with the main challenges of risk of lodging, indeterminate growth, pod shattering and low competitiveness to weeds.

In order to identify lentil genotypes suitable for cultivation in Germany, the project 'LinSel' was funded by the Federal Ministry of Food and Agriculture. Among other approaches, the genetic resources of the IPK gene bank were screened and a selection of 30 accessions was cultivated in a field trial at the University of Hohenheim in the year 2020. The seed size of the accessions ranged from a thousand kernel mass of 20 g to > 100 g. Two thirds of the accessions showed a greenish/yellow testa (sometimes spotted), and the others a green, rose or black testa. The embryo was mainly yellow; five of the 30 accessions had green or orange/red embryos. The period from sowing to harvest ranged from 108 to 122 days. The yield of marketable grains ranged from 0.04 g to 2.05 g per plant. 12 of the 30 lentil accessions showed shattering resistant pods. The lodging susceptibility of the lentil accessions ranged from 2.5% to almost 90%. The accessions with short growing period and high shattering resistance match our demand for varieties compatible with climate change.

With these data, we are able to multiply seeds of suitable varieties in the next step of the project 'LinSel' and to advise farmers on the choice of varieties. Furthermore, with the detailed characterization of the different accessions, we offer a sound basis to continue breeding work.

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Sainfoin (*Onobrychis viciifolia* Scop., legume family) – The future star in sustainable crop cultivation strategies?

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Sainfoin (*Onobrychis viciifolia* Scop., legume family) originates from South Central Asia and was introduced into Europe in the fifteenth century, when it was extensively cultivated. It is a re-emerging leguminous forage that contains condensed tannins and is traditionally grown as a long-term perennial ley in Europe, Asia and North America, where it is used primarily for livestock feed. Another benefit is its resistance against most common pests and diseases. Nowadays, further properties are also of interest, including nitrogen fixation, attractiveness for bees and other insects, drought tolerance, and usage as a co-substrate for the biogas processes.

In total, 45 accessions were cultivated over three years (2017-2019), 40 *O. viciifolia* samples (38 genebank accessions and two control cultivars Perly and Taja) and five wild samples (*O. altissima*, *O. arenaria*, *O. transcaucasica*). Accessions were characterized for 11 agronomical and morphological traits with a special focus on biomass yield of different cuts over three years.

After three years of cultivation, the biomass yield of the first cut was highest for most accessions compared to the previous years, despite lack of irrigation and fertilization throughout the whole cultivation process. Yield of the different accessions ranged between 0 and 124 dt/ha in the first, 4 and 312 dt/ha in the second and 9 and 531 dt/ha in the third year respectively.

Counting visits of pollinators confirmed that sainfoin is highly attractive to pollinating insects, particularly honey bees, but also lots of other insects like bumble bees and butterflies.

Onobrychis viciifolia is flower-rich, insect-friendly, has an impact on biodiversity, shows the typical legume nitrogen fixation and is undemanding in terms of water supply. In addition, due to the high tannin content, good methane productivity and experimental proven process stabilizing effects in a biogas plant, sainfoin is an interesting co-substrate for the biogas process. With all these positive properties sainfoin could be an interesting crop for future cultivation strategies.

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