EUCARPIA

NUE-CROPS

Breeding for Nutrient Efficiency

Joint Meeting of EUCARPIA Section
Organic & Low-Input Agriculture and EU NUE-CROPS Project
Göttingen, Germany, 24. – 26. September 2013

- Conference Booklet -

GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN

Photographers of the cover pictures:
Root: Catharina Meinen, tomato: Bernd Horneburg, oilseed rape: Sebastian Miersch,
all from the Georg-August-Universität Göttingen, Department of Crop Sciences

EUCARPIA

EUROPEAN ASSOCIATION FOR RESEARCH IN PLANT BREEDING
EUROPÄISCHE GESELLSCHAFT FÜR ZÜCHTUNGSFORSCHUNG
ASSOCIATION EUROPÉENNE POUR L'AMÈLIORATION DES PLANTES

Joint Meeting of EUCARPIA Section

Organic & Low-Input Agriculture
and
EU NUE-CROPS Project

Göttingen, Germany, 24 – 26 September 2013

Scientific committee

Heiko Becker, Göttingen
Edith Lammerts van Bueren, Wageningen
Carlo Leifert, Newcastle
Kristian Thorup-Kristensen, Copenhagen

Organizing committee

Heiko Becker
Antje Schierholt
Sabine von Witzke-Ehbrecht
Sabine Hippe
Wolfgang Link
Haiko Brandes

ISBN- Nr.:

Program

Day 1, Tuesday, 24 September

11:00 Registration, poster mounting, soup, finger food and drinks

<u>Session 1:</u> **Basic concepts and methodologies to improve nutrient efficiency**
(Chair: Edith Lammerts van Bueren)

13:00 **Welcome addresses** (*Beat Boller*, President of EUCARPIA, CH)

13:15 **Keynote: Kristian Thorup-Kristensen** (University of Copenhagen, DK) - Combining agronomic and breeding approaches for improved nutrient use efficiency

13:50 **Keynote: Bill Thomas** (James Hutton Institute, UK) - Association genetics of nitrogen use efficiency parameters in winter barley

14:25 *Hwat Bing So* (CAAS, Beijing & Griffith University, Australia) – Characterising nitrogen and water use efficiency of Chinese wheat and maize varieties through field and lysimeter trials (part of the NUE-CROPS Project)

14:50 - 15:20 Coffee Break

15:20 *Andreas Stahl* (Justus Liebig University Gießen, D) - Nitrogen use efficiency in winter oilseed rape: Characterization and phenotyping of a Brassica napus diversity set

15:40 *Jose Rafael Chan Navarrete* (Wageningen University, NL) - Evaluation of NUE in spinach with a hydroponic system using the Ingestad Model

16:00 *Pauline Kerbiriou* (Wageningen University, NL) - Breeding lettuce for improved resource capture, root functioning and robustness

16:20 *Dorcus Gemenet* (University of Hohenheim, D) - Genetic variation in West and Central African Pearl Millet and association mapping for low phosphorus tolerance based on DArT markers

16:40 **Keynote: Angharad Gatehouse** (Newcastle University, UK) - Quantitative proteomics to study crop plant response to contrasting fertilisation regimes

19:00 Come together and Conference Dinner (Old Town Hall, Göttingen)

Day 2, Wednesday, 25 September

Session 2: **Breeding programs and research on nutrient efficiency** (Chair: Heiko Becker)

8:30 *Franziska Löschenberger* (Saatzucht Donau, A) - Analysis of genotype by environment interaction in an international ring test related to breeding for organic agriculture

9:00 *Monika Messmer* (FiBL, CH) - Genotype x management interaction for nutrient use efficiency (NUE) of maize varieties tested under different tillage and fertilization regimes

9:30 **Keynote: Jonathan Lynch** (Pennsylvania State University, USA) - Steep, cheap, and deep: breeding targets for deeper roots

10:05 - 10:30 Coffee Break

10:30 *Sara Brumlop* (University of Kassel, D) - N-uptake in winter wheat pure line varieties and winter wheat composite cross populations in the F11

10:50 *Willmar Leiser* (University of Hohenheim, D) - Selecting sorghum for adaptation to low phosphorus soils in West Africa

11:10 *Péter Mikó* (Hungarian Academy of Sciences, HU) - Comparison of different breeding strategies of cereals through different environments

11:30 *Antonin Le Campion* (INRA, F) – Is low input management a good selection environment to screen winter wheat genotypes adapted to organic farming?

11:50 *Frédéric Rey* (ITAB, F) - Organic seeds and plant breeding: the stakeholder's uses and expectations

12:30 Departure to Excursion

13:15 KWS Saat AG, Einbeck: Lunch (Soup and finger food) & Introduction to KWS

15:00 **Keynote: Walter Schmidt** (KWS, D) - Experiences from organic maize breeding and prospects of coevolutionary breeding
Demonstration of breeding and research activities

16:00 Demonstration of breeding and research activities Experimental Station Wiebrechtshausen

19:00 Dinner and Poster Session (Central Lecture Hall Building, Göttingen)

Day 3, Thursday, 26 September

<u>Session 3:</u> **Genetic and agronomic advances in nutrient use efficiency of four major crops: Results from the NUE-CROPS project** (Chair: Carlo Leifert)

8:30 *Peter Werner* (KWS, UK) - The interaction of nitrogen with yield in wheat

8:50 *Thomas Presterl* (KWS, D) - Improving nitrogen use efficiency in maize

9:10 *Heiko Becker* (Georg-August-Universität Göttingen, D) - Breeding strategies to improve nitrogen use efficiency (Nit-UE) in oilseed rape

9:30 *Cesar Ospina* (Wageningen University, Agrico, NL) - Diversity of crop development traits and nitrogen use efficiency among potato varieties grown under contrasting nitrogen regimes

9:50 *Tim George* (James Hutton Institute, UK) - Getting to the root of phosphorus use efficiency in potato

10:10 Coffee Break

10:40 *Dorte Dresboll* (University of Copenhagen, DK) - Model simulation of cropping system NUE as affected by genotype variation in NUE based on different plant traits

11:00 *Jian Wu* (CAAS, Beijing) - QTL mapping of NUE in *Brassica rapa* and maize

11:20 **Panel discussion**: Improving resource use efficiency - where do we go from here?
Panel members: *Carlo Leifert*, Chair (Newcastle University, UK), *Hartwig H. Geiger* (University of Hohenheim, Germany), *Angharad Gatehouse* (Newcastle University, UK), *Franziska Löschenberger* (Saatzucht Donau, A), *Beat Boller* (Agroscope Reckenholz, CH)

12:50 **Closing remarks** (*Edith Lammerts van Bueren*, Wageningen University, NL)

13:00 – 14:00 Lunch

14:00 Excursion* to the Experimental Station Reinshof, Universität Göttingen

14:00 Guided Tour Göttingen City*

*) Please register on September 24 at the registration desk

Oral Contributions

Session 1

Basic concepts and methodologies
to improve nutrient efficiency

Combining agronomic and breeding approaches for improved nutrient use efficiency

Kristian Thorup-Kristensen

University of Copenhagen, Department of Plant and Environmental Sciences; ktk@life.ku.dk

Many studies are made on genes, genotypes and breeding approaches aimed at improved nutrient use efficiency (NUE). However, crops are grown in cropping systems interacting with their environment and the agricultural management they are subjected to. What farmers and society need is improved NUE of cropping systems, not of single crops. It is important to keep in mind, that NUE is not a trait of a genotype, but a "trait" of the crop or cropping system, determined by the interaction between Genotype, Environment and agricultural Management (GxExM).

Better NUE can be achieved by a range of approaches, by improved fertilizer management, growing catch crops or by improved crop rotations. When trying to optimize NUE in a specific field, these other methods typically have much larger potential for improving NUE than the choice of improved genotypes. However, the smaller effect of genotypes is more easily achieved on larger areas, by choosing the efficient genotypes over other less efficient ones, while most of other approaches require special attention from the farmer each year.

The choice is not between genotypes or agronomic measures, both are needed. Both because they interact, and because the can solve different aspects of the NUE problems. Improved NUE of genotypes must be directed at the farming system they are going to be grown in, e.g. the plant traits needed for high NUE are quite different in a low input organic system compared to a high input conventional system.

Crop root growth is a key factor in improving nutrient use efficiency of crops and cropping systems. It is important, as extensive root growth is needed to bring the crop into contact with the spatially distributed soil resources. Deep rooting is important for crop productivity as well as for environmental effects, as it brings the crop into contact with deep resources of water and nitrogen, otherwise left unexplored. However, deep rooting or other aspects of rooting are not included in breeding programmes.

We have been working on many aspects of crop root growth, differences among crop species and how they can be utilized for improved crop rotations as well as root growth of catch crops and their significance for improved nitrogen management. Currently we are working on genotypic variation in root growth and function, mainly in wheat. By drawing from the results from this root research, the combination of agronomic and breeding approaches for improved nutrient use efficiency will be discussed.

Also the term nutrient use efficiency (NUE) itself will be discussed. It is far from well defined, and sometimes it is used with directly contradictory meanings. There is a need to clear up this concept and define more precisely we are trying to achieve.

Association genetics of nitrogen use efficiency parameters in winter barley

William (Bill) Thomas[1], Guillaume Barral-Baron[2], David Harrap[2], Allan Booth[1], Richard Keith[1], Chris Warden[1], Joanne Russell[1], Robbie Waugh[1], Peter Werner[2] and Luke Ramsay[1]

[1]James Hutton Institute, Invergowrie, Dundee, DD2 5DA, UK, Bill.Thomas@hutton.ac.uk,
[2]KWS (UK) Ltd, 56 Church Street, Thriplow, Royston, Herts. SG8 7RE, UK,

Introduction and Materials & Methods

We grew over 160 elite Northern European winter barley cultivars selected to represent over 50 years of European barley breeding in 5 site/season trial combinations with known available soil mineral nitrogen content. Each trial was grown with three fertiliser regimes in a split plot design with partial replication; no nitrogen application, a malting nitrogen application and a feed nitrogen application. Plots were kept free from disease with a standard fungicide regime. The lines were a mixture of two- and six-row ear types including several deficiens types, in which the lateral florets are vestigial, amongst the two-rows.

Samples were taken from each plot prior to harvest and oven dried. The proportions of grain and straw in each dried sample were then used to derive harvest index. The plots were then harvested and grain yield and nitrogen content (using Near Infra Red transmittance analysis) recorded. The straw samples were ground up and used to estimate the nitrogen content of the straw using the Dumas combustion method. The above measurements were combined with available nitrogen and yield (biomass and grain) data to derive measures of nitrogen uptake efficiency and utilisation efficiency (both total and grain).

Results & Discussion

Analysis of the data revealed that there was considerable genetic variation for all the traits measured but that the interaction of genotype with fertiliser treatment was small in comparison to the genotype interactions with site and season. This suggests that breeding specifically for low nitrogen inputs over a wide range of environments is unlikely to be effective. It was also apparent that breeding progress in two and six row barley for nitrogen uptake and utilisation efficiency clearly differed with uptake efficiency of the six rows increasing faster over time than that of the two rows. In contrast, the grain utilisation efficiency of the two rows has increased faster over time, a trend that is mirrored in grain yield.

All the lines were genotyped with over 6500 markers, representing Single Nucleotide Polymorphisms in known barley genes, using the barley 9K Illumina Infinium assay. We then combined the genotypic data with the phenotypic data in QTL x Environment genome wide association scans using Genstat v15. This revealed significant associations for all the use efficiency parameters that we measured. Some of the highly significant associations were located in genomic regions where genes known to be involved in nitrogen mobilisation and metabolism exist. Some effects were associated with SNPs in approximate equilibrium, highlighting unselected regions of the genome that could be used in breeding for improved components of nitrogen use efficiency.

Acknowledgements

This work was conducted under a work package of the EU FP7 ‘Improving nutrient use efficiency in major European food, feed and biofuel crops to reduce negative environmental impacts of crop production’ (NUE Crops) - EU-FP7 222-645 (2009 - 2014) led by Carlo Leifert of the University of Newcastle.

Characterising Nitrogen and water use efficiency of Chinese wheat and maize varieties through field and lysimeter trials (part of the NUE-CROPS Projects)

Hwat Bing So[1,5], *Juan Li*[1], *WY Sun*[1], *XL Pan*[1], *LM Gu*[2], *JF Wang*[2], *LJ Shao*[2], *GH Mi*[3], *YP Tong*[4], *P Liu*[2], *BQ Zhao*[1]

[1]*Institute of Agric Res and Regional Planning, Chinese Academy Agricultural Sciences (CAAS), Beijing;* [2]*Shandong Agricultural University, Tai-an, Shandong(SAU);* [3]*Chinese Agricultural University, Beijing(CAU),* [4]*Institute of Genetics and Development Biology, Chinese Academy of Science (CAS);* [5]*Environmental Futures Center, Griffith University, Nathan, Qld, Australia, h.so@griffith.edu.au*

Introduction

China has moved from the exclusive use of organic fertilizers in 1950 to the current predominantly mineral fertilizer usage in their quest to increase food production to feed its growing population. The policy of maximizing food production resulted in a low Nit-UE of 35 %, begging the question of what happen to the other 65 % of applied N. This paper reports on the results of field and lysimeter trials in Northern China to investigate the effect of mineral and organic fertilizers and irrigation on the yield, NitUE and WUE (Water use eff) of 4 winter wheat and 4 summer maize varieties within an intensive wheat maize rotation farming system commonly practiced in Northern China.

Materials and Methods

Field trials were established at the CAAS Agric Experimental Station in Dezhou, Shandong to investigate the effect of type and rate of N fertilizers, and irrigation on 4 wheat and 4 maize varieties with different NUEs. To keep the trials to manageable size, 2 complementary trials were set up. At the Ling Xian site, a trial consisting of 10 treatments (type and rate of N fertiliser) x 4 varieties x 3 replications = 120 plots were established for each of wheat and maize in rotation. Irrigation was similar to local farmer's practice and is denoted as 100 %. The second trial at the YuCheng site consists of 6 treatments x 3 irrigation rates (100 %, 70 %, 40 %) x 2 varieties x 3 replications = 108 plots for both wheat and maize.

Samples from 2 contrasting varieties were sampled for gene expression analysis (qRT-PCR method) on wheat at CAS and maize at CAU. As detailed losses of N (leaching and volatilization) are difficult to measure in the field, part of the field trial were duplicated in large lysimeters (2.4 x 2.4 x 2 m deep) at the Shandong Agricultural University where yield, leaching losses and ammonia volatilization losses were monitored throughout the growing season for each crop.

Results and discussion

The results show that there was no effect of irrigation levels in the field, due to the high water table present at approximately 1.75-2 m which has supplied adequate water to the crops. For the first three years, the results showed that at the same level of N supply, wheat fertilized with urea displayed yields 50% greater than wheat fertilized with cow manure as manure only released approximately 1/3 of its total N during the winter cropping season. Maximum yields were achieved with 180 kg available N/ha. Shimai15 displays the highest yields, followed by Kenong9204 and Jimai19, with Weimai8 the lowest yield. These differences were largely associated with the development of the photosynthetic sink (number of grains/ha).

Similarly, with the same rate of N application, maize yielded 20 % more under urea compared to manure, as manure released approximately 50 % of its total N during the warmer and wetter summer cropping season. Maximum yields were achieved with 120-150 kg avail N/kg. At high rates of fertilizer, XY335 yielded best, with LN14 and ZN99 being intermediate and NE9 being the worst. At lower rates of fertilizer, they are not significantly different. One candidate gene for NUE (CGN1) was identified in wheat, and 6 in maize. Results from the lysimeter trials show that significant losses of N occurs through leaching and ammonia volatilization (AV). These results will be presented and discussed in greater detail at the meeting.

**Nitrogen use efficiency in winter oilseed rape:
Characterization and phenotyping of a *Brassica napus* diversity set**

Andreas Stahl, Benjamin Wittkop, Rod Snowdon, and Wolfgang Friedt

Department of Plant Breeding, IFZ Research Centre for Biosystems, Land Use and Nutrition, Justus Liebig University, Heinrich-Buff-Ring 26-32, 35392 Giessen, Germany, andreas.stahl@agrar.uni-giessen.de

Nitrogen is essential for plant growth and crop productivity. Its adequate application as fertilizer is essential for sufficient crop yields. Unused nitrogen, however, can escape from the agricultural production system by run-off, nitrate leaching or losses from volatile nitrous oxide or ammonia, potentially causing environmental damages in other ecosystems. Additionally, since mineral fertilizer production by the Haber-Bosch process is energy dependent, increasing prices and the goal of reduced carbon dioxide emissions increase the necessity for efficient nitrogen utilization.

Oilseed rape, Europe's most important oilseed crop and the second most important in the world, is efficient at nitrogen acquisition but releases noteworthy amounts before and after harvest. Detection of genetic variation for nitrogen use efficiency and its use through breeding therefore has the potential to increase sustainability of nitrogen use in agricultural production. One important aspect to consider is the role of variation in root architecture and function and its response to reduced nitrogen availability.

During the 2012-2013 growing season a set of 30 highly diverse *B. napus* genotypes, including old varieties and novel, resynthesized rapeseed lines, was investigated in an *in vitro* growth system and in Mitscherlich pots for analysis of different phenotype responses under different nitrogen levels. Moreover, 90cm deep containers filled with 130 kg of soil and fertilized with an equivalent to 75 and 235 kg N ha^{-1} were used to grow the same materials under semi-controlled conditions simulating a field soil environment. The results provide first insights into *B. napus* root and shoot development in the context of nitrogen acquisition. Furthermore, measurement of nitrogen content in leaves, stems, and seeds will allow the identification and characterization of genetic variation for remobilization of nitrogen from senescent plant organs into mature seeds.

Evaluation of NUE in spinach with a hydroponic system using the Ingestad Model

Rafael Chan-Navarrete[1], *Asako Kawai*[1], *Oene Dolstra*[1],
Edith T. Lammerts van Bueren[1,2] *C. Gerard van der Linden*[1]

[1] *Wageningen University and Research Centre, Wageningen UR Plant Breeding, Droeendaalsesteeg 1, 6708 PB Wageningen, The Netherlands, jose.channavarrete@wur.nl,*
[2] *Louis Bolk Institute, Driebergen, The Netherlands*

Nitrogen use efficiency (NUE) is an important trait that can contribute to sustainable agriculture. Spinach is a crop with a high demand for nitrogen, but it has low NUE which leads to leaching of nitrogen. To develop a breeding program for NUE in spinach, it is essential to determine genetic variation for nitrogen use and to identify traits that significantly contribute to NUE. This study aims to understand the factors determining nitrogen uptake efficiency (NUpE) and nitrogen utilization efficiency (NUtE) of spinach by studying the response of plant growth in both roots and shoots to different N levels.

The experiments were carried out with 22 spinach accessions in a hydroponic system for 4 weeks for an evaluation under controlled conditions of relevant root and shoot traits which are also evaluated under field conditions in a parallel study. The Ingestad model was used to maintain a steady-state N level in the plants. N solution was applied to keep relative growth rate of 0.18 (high N treatment) and 0.14 (low N treatment). Traits of interests were shoot dry weight (SDW), root dry weight (RDW), root length (RL), specific root length (SRL), leaf area (LA), specific leaf Area (SLA), and chlorophyll content (SPAD measurements). Plants were harvested and measured two and four weeks after transplanting in the hydroponic system.

The effect of N treatment on plant growth was significant at week 4. Spinach adapted to low N conditions by reducing the aboveground biomass and increasing root biomass. Some genotypes adapt to low N by producing longer and thinner roots. These contribute to more efficient acquisition of N by increasing root surface and exploring deeper soil layers. With N limited, carbon assimilates may be allocated more to sugar and cell walls than proteins, which would explain the reduced leaf area and the changed production of roots under low N. The root traits together with SLA, LA, SDW and RDW are useful criteria that are linked with the performance of spinach cultivars under low N conditions.

Breeding lettuce for improved resource capture, root functioning and robustness

P.J. Kerbiriou[1,2], *T.J. Stomph*[2], *E.T. Lammerts van Bueren*[1], *P.C. Struik*[2]

[1]*Wageningen UR Laboratory of Plant Breeding, P.O. Box 386, 6700 AJ Wageningen, The Netherlands, Pauline.Kerbiriou@wur.nl*
[2]*Centre for Crop Systems Analysis, Wageningen UR, P.O. Box 430, 6700 AK Wageningen, The Netherlands,*

Root traits related to resource capture have not yet been fully exploited for selection in breeding programmes for lettuce. In lettuce, modern genotypes have been bred under conditions including high levels of input. Consequently these genotypes invest little resources in root growth and root functioning. This breeding strategy makes modern lettuce varieties less adapted to low-input/organic growing conditions, in which nitrate availability varies with soil moisture content, soil temperature over time and across the soil profile. These varieties may also be more vulnerable to variable conditions. To create more robust varieties it is necessary to identify which root traits are important to optimize resource capture and root functioning. We therefore studied root growth and resource capture of lettuce exposed to temporary drought, to permanent but localized drought and to localized nitrate shortage in two greenhouse pot trials. We also tested the effect of transplanting seedlings of different sizes on root growth and resource capture of four cultivars in three field experiments under organic growing conditions. The results of our research provided a physiological conceptual framework for the spatial and temporal dynamics of nitrate and water capture, and their interactions. These results also provided insight in the efficiency of the use of these resources for shoot growth. We translated that framework into a strategy to breed for robustness in lettuce, which will be presented in this contribution.

Genetic Variation in West and Central African Pearl Millet and Association Mapping for Low Phosphorus Tolerance based on DArT Markers

Dorcus C Gemenet[1], *Charles Tom Hash*[2], *Folkard Asch*[1], *Albrecht E Melchinger*[1], *Roger Zangre*[3], *Ousmane Sy*[4], *Moussa D Sanogo*[5] *and Bettina IG Haussmann*[1]

[1]*University of Hohenheim, Institute of Plant Breeding, Seed Science and Population Genetics, 70593 Stuttgart, Germany, chepkesis@yahoo.com;* [2]*ICRISAT Sahelian Centre, Niamey, Niger; INERA, Ouagadougou, Burkina Faso;* [4]*ISRA, Bambey, Senegal;* [5]*IER,Cinzana, Mali,*

Introduction

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is a food security crop for millions living in drylands of Africa and Asia. Despite its unique adaptability to extreme environments, its production on acid sandy soils of the Sahel is severely limited by erratic rainfall and poor soil fertility, especially low phosphorus (P) soils. Our research aims to elucidate the genetic variation of West and Central African (WCA) pearl millets for low P tolerance, estimate quantitative-genetic parameters to derive an appropriate breeding strategy, and to identify molecular markers associated to the trait.

Methodology

We evaluated 102 landraces from WCA, 160 landrace-derived inbred lines as well as 160 testcrosses from the inbred lines in four locations in Niger, Burkina Faso, Mali and Senegal over two years (2010 and 2011 for landraces, 2011 and 2012 for inbred lines and testcrosses). At each location, the experiments were laid in two treatments, high P (with P fertilization) and low P (without P fertilization), with initial soil bray P1 values of <6. Genetic variation for grain yield under low P was evaluated alongside other component traits. The inbred lines were also genotyped with 407 DArT markers in a whole genome scan.

Results

Preliminary results revealed significant effects for genotypes, fertilization treatment, genotype x treatment interaction, as well as genotype x location interaction, with the amount of rainfall explaining most of the genotype x location interaction observed. This underlines the importance of studying the interaction between water stress and low P tolerance. Grain yield reductions under low-P treatment of 30%, 16% and 12% were observed for landraces, inbred lines and testcrosses respectively. Initial results with DArT markers reveal grouping of the inbred lines into about five subgroups, while PCA reveals no definite structure among the inbred lines. Data analysis is still ongoing.

Conclusion

It is hoped that significant and stable associations will be found between the DArT markers and the phenotypic data in an effort towards developing initial molecular markers for low P tolerance in pearl millet.

Quantitative proteomics to study crop plant response to contrasting fertilisation regimes

A.M.R. Gatehouse, C. Tetard-Jones, L. Rempelos, M.G. Edwards, J. Cooper, C. Leifert

Molecular Agriculture Group, Newcastle Institute for Research on Sustainability, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK, a.m.r.gatehouse@newcastle.ac.uk

Negative environmental impacts from mineral fertilisers and pesticides used in conventional cropping have raised concern over the sustainability of arable crop production. Organic cropping uses alternatives that avoid many of these negative environmental effects; however, crop yields can be significantly reduced, possibly due to a lower proportion of plant available nutrients. Functional genomics was used to gain insights into the molecular effects of organic compared to conventional cropping systems on plant utilisation of nutrients in two important crops, winter wheat (*Triticum aestivum*) and potato (*Solanum tuberosum*).

For wheat, flag leaf N and P composition were shown to be significant drivers of differences in protein spot abundance, including major proteins involved in nitrogen remobilization (degradation products of RuBisCO large subunit, glutamine synthetase), photosynthesis (e.g. RuBisCO activase, oxygen evolving enhancer protein, Cytochrome b6-f complex), metabolism (e.g. O-methyltransferase) and stress response (Catalase, Cu/Zn superoxide dismutase). Similarly, for potato leaf N and P composition were significant drivers of protein expression, particularly proteins involved in photosynthesis (e.g. large subunit of RuBisCO, RuBisCO activase and the photosystem I reaction centre), which were at higher abundances in potato leaves grown under mineral fertiliser regimes. Proteins known to be induced in response to general stress, (dehydroascorbate reductase and Glutathione S-transferases) were also shown to be up-regulated under mineral fertilisation, possibly associated with higher Cd composition, whereas two proteins known to be involved in biotic stress (1,3-b-D-glucan glucanohydrolase; putative Kunitz-type tuber invertase inhibitor) were more abundant under compost fertilisation. Results showed that for both crops, switching from mineral to organic fertilisers led to reduced N availability, a significant change in leaf protein expression and lower yield.

Using a functional genomics approach, we were able to identify proteins that are linked to causal genes, enabling the potential development of functional molecular markers for more rapid selection of varieties for improved nutrient use efficiency.

Oral Contributions

Session 2

Breeding programs and research on nutrient efficiency

Analysis of genotype by environment interaction in an international ring test related to breeding for organic agriculture

Franziska Löschenberger[1], *Almuth Müllner*[2], *Fabio Mascher*[3], *David Schneider*[3], *Gheorghe Ittu*[4], *Ian Toncea*[4] *and Bernard Rolland*[5]

[1]*Saatzucht Donau, Probstdorf, Austria (AT), franziska.loeschenberger@saatzucht-donau.at;*
[2]*BOKU/IFA Tulln, (AT),* [3] *Agroscope Changins-Wädenswil ACW Switzerland (CH),*
[4]*RICIC Fundulea, Romania (RO),* [5]*INRA Rennes (F)*

Within the framework of the COST action 860 SUSVAR (Sustainable low-input cereal production: required varietal characteristics and crop diversity), a ring test with 14 winter wheat genotypes from 5 different countries (AT, CH, D, FR, RO) was performed in 36 field trials between 2006-2008 in Romania, Switzerland, France and Austria. 13 trials were grown under organic conditions. Based on the observation of about 43 phenotypic traits, the ring test aimed at comparing the performance of wheat genotypes under low and high input cropping practices in many different European environments. Overall, 13 trials were sown under organic conditions (ORG), and out of the conventional trials, 6 were sown without N supply "no input" (NI), 8 under "low input" (LI) conditions using maximum 100kg N, and 9 trials were sown under "high input"(HI) conditions All trials were conducted without fungicide or growth regulator application. **GGEBiplots** were used for the analysis of genotype stability and differential behaviour under ORG, NI, LI and HI conditions. Results were more variable between countries and individual trials than between systems. To represent all countries in each set, environments were re-grouped combining ORG +NI in N0 and LI +HI in NS, i.e. groups without and with synthetic nitrogen.

Variance components and heritabilities were calculated for N0 and NS plus additional groupings of environments (ORG, NI, LI, HI; years and countries). Heritability was 0.85, 0.83, 0.44,and 0.61 for HI, LI, NI, and ORG, respectively. Subsequently, **Relative Selection**

Efficiencies (RE) were calculated in order to compare direct and indirect selection for ORG, N0 and NS and for countries and years according to Weber et al. (2012).
The question: **"Can 'three years of trialling' be replaced by 'trialling in one year"** was answered by comparing sets of 12 trials from 2006 and 2007 with a set comprising 12 trials for 2006-2008 (4 in each year). Using 2006 as test environment gave a poor RE with respect to all 3 years' results, while selection in the year 2007 alone was sufficiently efficient.
Many traits, e.g. plant growth habit or leaf inclination as well as soil coverage were scored at different developmental stages. Data for 13 traits are represented in all 4 intensity groups, 31 traits are represented in both the N0 and NS group of trials. Pearson correlation analysis revealed for many traits high heritability across the four systems HI, LI, NI and ORG. Based on the results, suggestions are made for conduction of a commercially sustainable breeding program for organic agriculture.

Reference:

Weber V, AE Melchinger, C Magoroskosho, D Makumbi, M Bänziger and GN Atilin (2012): Efficiency of Managed-Stress Screening of Elite Maize Hybrids under Drought and Low Nitrogen for Yield under Rainfed Conditions in Southern Africa. Crop Sci 52:1011-1020.

Genotype x management interaction for nutrient use efficiency (NUE) of maize varieties tested under different tillage and fertilization regimes

Monika Messmer[1], *Noémi Uehlinger*[1,2], *Alfred Berner*[1], *Johannes Scholberg*[2], *Paul Mäder*[1]

[1]*Research Institute of Organic Agriculture (FiBL), Ackerstr. 21, CH-5070 Frick, Switzerland;, Monika.messmer@fibl.org,* [2] *Biological Farming Systems Group, Wageningen University (WUR), Droevendaalsesteeg 1, 6708PB Wageningen, The Netherlands*

Most varieties have been selected under high input conditions, including seed treatment, herbicide applications, as well as optimal levels of fast releasing fertilizers. Under organic farming nutrient release is dependent on the temperature and biological activity of the soil and its interaction with the declining residues from previous crops and applied quantity of farmyard manure. As a consequence it is not always possible to match nutrient release with crop demand over time. This effect is even more severe under conservation tillage. To promote conservation tillage in organic farming, it is necessary to identify cultivars that show high nutrient use efficiency (NUE) under these conditions. While there is substantial evidence that breeding for low N input conditions selection is more efficient under severe N stress than under high input conditions only few studies have been conducted to demonstrate the difference in selection gain between organic and inorganic fertilization or between different soil tillage management. The objectives of the study were (i) to quantify the NUE of maize (*Zea mays* L.) genotypes under different tillage regimes and fertilization levels, (ii) to compare the effect of slow releasing organic versus inorganic fertilizer, and (iii) determine genotype x management interaction.

We tested six maize varieties under conventional (CT) and reduced tillage (RT), applying five different fertilization regimes (unfertilized control, slurry with either 85 or 170 kg/ha total N, inorganic NPK fertilizer with either 85 or 170 kg/ha total N) with four replications in a split split plot design. Conventional tillage (CT) was carried out using a mouldboard plough tilling the upper 18-20 cm of the soil. The reduced (RT) tillage treatment was implemented with a stubble cleaner that inverted the top 5 cm. The field trials were carried out on two organically managed farms: one on loamy soil in Muri/AG, Switzerland in 2009 and the other one on silty loam (Luvisol) in Aesch/BL, Switzerland in 2010. Weed pressure, anthesis, plant height and chlorophyll content were assessed. At anthesis and silage harvest, dry matter content, dry matter yield (DMY), nitrogen (N), phosphorus (P) and potassium (K) concentration were determined as well as silage quality parameters including netto energy lactation (NEL).

The six different maize varieties tested in Muri 2009 and Aesch 2010 under different tillage and fertilization regimes had a significant effect on almost all traits. Tillage regime had no significant effect on DMY, although RT caused significant increases in weed scores, higher dry matter content and reduced chlorophyll content. Significant genotype x tillage x fertilization interaction were observed for weed incidence and NEL, but not for DMY. Significant variety x fertilization interaction was detected for P concentration. Significant variety x tillage x fertilization interactions were detected for N use efficiency (i.e., dry matter yield per kg Navailable), P use efficiency, and K use efficiency. We concluded that selection on dry matter yield can be performed under standard conditions (CT, NPK2), whereas selection on nutrient use efficiency is highly influenced by the management conditions resulting in the selection of different genotypes for different cultivation systems. In order to improve NUE, breeding and management should be optimized simultaneously.

Steep, cheap, and deep: breeding targets for deeper roots

Jonathan Lynch

Department of Plant Science, The Pennsylvania State University, University Park, PA, USA, JPL4@psu.edu

In general, two broad classes of soil resources are those that are concentrated in the topsoil, including P and K, and those that are concentrated in deep soil strata over the growing season, including nitrate and water. Crop genotypes that colocalize root foraging activity and soil resource availability in time and space will have superior soil resource acquisition. Optimal root phenotypes should also use metabolic resources efficiently, as root metabolic costs can be significant limitations to crop growth and yield, especially in resource-limited environments.

Root traits that enhance topsoil foraging and thus P acquisition include shallow axial root growth angles, adventitious rooting, short lateral branches, long root hairs, and traits that reduce the metabolic costs of root growth, including root etiolation in dicots and root cortical aerenchyma in monocots. These traits are being deployed in crop breeding programs to improve the P acquisition of soybean in China and common bean in Africa and Latin America.

Architectural traits that speed the descent of roots into deep soil strata include steep axial root growth angles, reduced lateral branching, and a reduced number of axial roots. Root growth angles directly affect rooting depth, whereas lateral branching and the number of axial roots affect rooting depth by altering the allocation of plant resources and by affecting intraplant root competition. In dicot species, architectural traits that increase rooting depth must be balanced with complementary traits that permit topsoil foraging for the acquisition of relatively immobile soil resources such as P and K. Anatomical traits can affect rooting depth by altering the metabolic cost of root growth and maintenance. These include root cortical aerenchyma, which reduces root metabolic costs by converting living cortical tissue to air space, and cortical cell file number, which affects the metabolic burden of the root cortex. Substantial genotypic variation for these traits is present in several crop species, that is associated with acquisition of deep soil resources such as water under terminal drought conditions and N in leaching environments.

Field based high-throughput phenotyping platforms are being used for direct phenotypic selection for optimal root phenotypes in crop breeding programs and to identify the genetic basis of such variation in several crop species.

N-uptake in winter wheat pure line varieties and winter wheat composite cross populations in the F_{11}

Sarah Brumlop, Maria R. Finckh

Group Ecological Plant Protection, Faculty of Organic Agricultural Sciences, University of Kassel, Nordbahnhofstraße 1a, D-37213 Witzenhausen; brumlop@uni-kassel.de

Introduction

In order to be able to adapt to changing environmental conditions, crop plants need a certain degree of diversity (Stevens 1942, Finckh 2008). The development of genetically diverse populations (composite cross populations, CCPs) instead of breeding entirely homogeneous pure line varieties by standard pedigree breeding methods is a strategy that aims at creating flexible varieties.

Material and Methods

Three winter wheat CCPs from the UK based on 20 modern wheat varieties (A) or a subset of either 12 high quality varieties (Q) or 9 high yielding parents (Y) were used. Since the F_5 the CCPs have been grown under organic (O) and conventional (C) conditions in two parallel sets at the University of Kassel without artificial selection applied. In addition, since the F_8 two A populations have been maintained as broadcast sown populations without mechanical weed control.

In 2011/12 the F_{11} of all 14 populations were compared in a replicated field trial to the mixture of the 20 parents and the three commercial wheat cultivars Achat, Akteur, and Capo.

N-uptake of the plants was measured at the beginning of stem elongation, at the flowering stage and in the ripe seeds and straw.

Samples of fresh plants were cut and dried for 72 hours at 60 °C. Seeds and straw were dried after harvesting and all samples were milled and analyzed for N-content using a CHN analyzer.

Nmin in the soil was measured in early spring, at the flowering stage and after harvest.

Results and Discussion

Overall, the differences among the populations in N-uptake appeared small. However, when comparing the conventionally and organically grown populations as two groups, in 2011, at flowering O- populations had taken up approximately 6% more N than the C-populations. These differences were not visible in early cut samples or in seeds and straw.

Comparing N-uptake and the amount of available Nmin in the soil, no strong relationship appears.

Sufficient seeds of the F_{10} were saved and a second year of field trials is on-going with the same populations in 2012/13. Detailed data including the second years data will be presented.

References

Finckh MR (2008) Integration of breeding and technology into diversification strategies for disease control in modern agriculture. *European Journal of Plant Pathology* **121**: 399-409.

Stevens NE (1942) How plant breeding programs complicate plant disease problems. *Science* **95**: 313-316.

Selecting sorghum for adaptation to low phosphorus soils in West Africa

Willmar L. Leiser[1,2], H. Frederick W. Rattunde[2], Eva Weltzien[2], Bettina I.G. Haussmann[1]

[1] Institute of Plant Breeding, Seed Science and Population Genetics, University of Hohenheim, 70593 Stuttgart, Germany, [2] International Crops Research Institute for the Semi-Arid Tropics, BP 320 Bamako, Mali. Email: willmar_leiser@uni-hohenheim.de

Sorghum (*Sorghum bicolor* L. *Moench*) is a staple crop of the Savannah Zone of West- and Central Africa. The adaptation of sorghum to the climatic and edaphic conditions of this zone is critical for food security, and increasingly for farm income. Most of Sub-Saharan African soils (75%) show plant nutrient deficiency (IFDC, 2006). Limited soil-phosphorus (P) availability is a serious and frequent constraint to sorghum growth and productivity across the range of rainfall zones in West Africa (Buerkert et al., 2001). We assessed grain yields and traits related to P uptake and P use efficiency of 70 diverse West African sorghum genotypes under –P (no P fertilization) and +P conditions at two locations in Mali over five years (2006 – 2010). The –P fields showed relative yield reductions of 2-59% compared to the +P fields. The use of statistical models to adjust for spatial trends in experimental fields was shown to increase the efficiency of genotype selection, especially in heterogeneous low P conditions (Leiser et al., 2012a)17 experiments with 70 sorghum genotypes conducted in Mali, West Africa, were analysed for grain yield using different mixed models including models with autoregressive spatial correlation terms. Spatial models (AR1, AR2. Furthermore we could show that sorghum germplasm from West Africa is generally well adapted to low P soils, with a generally strong relationship between performance under +P and –P. However genotype-by-phosphorus cross over type interaction was observed among some of the best yielding genotypes. Direct selection under –P conditions was predicted to give 12% more yield gain for P-limited conditions, relative to indirect selection under +P conditions (Leiser et al., 2012b). There was a large genetic diversity for P uptake and P utilization traits. Although P uptake traits were better at predicting grain yield across –P conditions than P use efficiency traits, selection for high yielding genotypes with a high P use efficiency is possible. Guinea landraces as a group showed slightly better adaptation towards –P, and included those genotypes with specific-adaptation to –P conditions. Inter-racial (Guinea x Caudatum) breeding lines showed on average better +P adaptation. Results of this study are pertinent for guiding national and international efforts to breed sorghum for small holder farmers in West Africa, and the identified genotypes with –P adaption will be useful for further breeding and research efforts.

References

Buerkert, A., A. Bationo, and H.-P. Piepho. 2001. Efficient phosphorus application strategies for increased crop production in sub-Saharan West Africa. Field Crops Research. 72: 1–15.

IFDC. 2006. Global leaders launch effort to turn around Africa's failing agriculture: new study reports three-quarters of African farmlands plagued by severe degradation. Available at: http://www.rockefellerfoundation.org/news/press-releases/global-leaders-launch-effort-turn

Leiser, W.L., H.F. Rattunde, H.-P. Piepho, and H.K. Parzies. 2012a. Getting the Most Out of Sorghum Low-Input Field Trials in West Africa Using Spatial Adjustment. Journal of Agronomy and Crop Science. 198: 349–359.

Leiser, W.L., H.F.W. Rattunde, H.-P. Piepho, E. Weltzien, A. Diallo, A.E. Melchinger, H.K. Parzies, and B.I.G. Haussmann. 2012b. Selection Strategy for Sorghum Targeting Phosphorus-limited Environments in West Africa: Analysis of Multi-environment Experiments. Crop Sci. 52: 2517–2527.

Comparison of different breeding strategies of cereals through different environments

Péter Mikó[1], Mária Megyeri[1], Márta Molnár-Láng[1], Géza Kovács†[1], Mariann Rakszegi[1], Jürg Hiltbrunner[2], Franziska Löschenberger[3]

[1]Agricultural Institute, Centre for Agricultural Research, Hungarian Academy of Sciences, PO Box 19., 2462-Martonvásár, Hungary; [2]Forschungsanstalt Agroscope Reckenholz-Tänikon ART, Reckenholzstrasse 191, 8046-Zürich, Switzerland; [3]Saatzucht Donau GmbH & Co KG, Saatzuchtstrasse 11, 2301-Probstdorf, Austria; miko.peter@agrar.mta.hu

In recent years needs have increased to start experimental studies on the investigation of the necessity of organic breeding in cereals. As a result of a national study in Hungary an organic emmer wheat variety (*Triticum turgidum* ssp. *dicoccum* 'Mv Hegyes') was released, and used by organic farmers. Moreover it is also part of an organic silage experiment. Meanwhile, an EU project has been started on an international level to gain solid results for encouragement of true organic breeding and VCU test in case of current legislative systems.

Aim of recent study was to compare the performance of several winter bread wheat (*Triticum aestivum* L.) varieties originated from different European countries under low input conventional and certified organic farming conditions. Effectiveness of different breeding strategies was also compared under the different agro-ecological conditions of this trial.

Material and methods

Altogether 37 winter bread wheat varieties were compared for 3 years in 3 countries (Hungary, Austria and Switzerland) in small plot trials with three replicated blocks under organic and low input conditions. While only organic trial was established in Switzerland, five sites were examined in this study. Nine of the 37 varieties were organically bred. These varieties together with 14 conventional varieties, 8 low input varieties from Switzerland and 6 varieties from Austria released after exclusive organic VCU test were compared for several agronomic traits, quality and other traits of importance in organic farming (e.g. soil coverage). Detailed data analyses were carried out in these variety-groups to evaluate the adaptability and performance of varieties grown on different sites, and to investigate the genotype-environment (G×E) interactions. Statistical evaluations were carried out with One- and Two-Way ANOVA, Principal Component Analyses (PCA) and Box-Whiskers Graphs (BWGs).

Results and discussion

Based on the results, there were differences between the varieties developed by different breeding methods in organic and low input fields. Regarding the examination of G×E interaction, PCA and BWGs revealed that Swiss organic site differed most from all the other sites, having greater plant height and yield but a lower hectolitre weight (PC1+PC2=59.55% of the cumulative variance). In contrary, Austrian organic site and Hungarian low input site showed the opposite of the Swiss site. The Swiss growing site differed significantly from most of the other sites in hectolitre weight, lodging and soil coverage. Lodging was higher in organic fields, than in low input fields. Soil coverage of the Hungarian organic growing site was significantly higher than most of the other sites. Effect of site on variety-groups resulted in later heading and bigger plant height, but lower yield and thousand kernel weight in organic field. Major differences between the variety-groups proved that growing site of breeding activities has measurable effects on the performance of bread wheat varieties.

The research work leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under the Grant Agreement n°245058-SOLIBAM, and from the National Science and Technology Office (*TECH_08-A3/2-2008-0397 - CONFU_08* – Hungary).

Is low input management a good selection environment to screen winter wheat genotypes adapted to organic farming?

Antonin Le Campion[1]*, François-Xavier Oury*[2]*, Jean-Yves Morlais*[1]*, Patrice Walczak*[3]*, Olivier Gardet*[4]*, Stephan Gilles*[4]*, Alexandre Pichard*[4]*, Bernard Rolland*[1]

[1]*INRA, UMR 1349 IGEPP, 35653 Le Rheu, France; bernard.rolland@rennes.inra.fr*
[2]*INRA, UMR 1095 GDEC, 234 av. du Brézet, 63100 Clermont-Ferrand, France*
[3]*INRA, UE Fourrages et Environnement, route de Saintes, BP 6, 86600 Lusignan, France*
[4]*Agri-Obtention, Chemin de la Petite Minière, 78280 Guyancourt, France*

The move toward sustainable and productive agriculture requires, among other, the design of new sustainable farming systems in which the variety will play a main role. Plant breeding strategies adapted to organic farming conditions have to deal with more limiting factors and a variable target environment. If in north-west France high input conditions do not give a good prediction of genotype performance in organic management, less is known about the relative stability of wheat genotypes between low input and organic management.

A retrospective analysis of 34 winter wheat trials conducted from 2004 to 2011 was perform to determine the relative ability of low input (LI) management to predict genotype performances in organic (ORG) farming system. Each year, ORG and LI (no fungicide and growth regulators, N balance sheet – 60 kgN) trials including 25 to 30 genotypes describing a large range of genetic diversity were sown in three different agro-climatic regions across north-west France.

Despite lower grain yields and grain protein contents in ORG trials we show that genotypes keep the relative same ranks among farming system. Spearman's rank correlations were high (Rs = 0,54 to 0,89) and genotype rank inversions had minor extent. Besides, a selection intensity of one third resulted in 65 % genotypes in common for yield and in 75 % genotypes in common for grain protein contents. Relative efficiency (RE) of indirect selection for ORG was calculated per year. Based on genotype mean yields among trials each years, RE were high and ranged from 0,84 to 1,26 underlying the value of LI indirect selection for ORG target environment. In contrast the unpredictability of genotype baking quality in organic conditions highlights the need to evaluate directly this ability in organic conditions.

Our results are consistent with a Swiss study which revealed important correlations between organic and low input crop management for yield and other traits (Schwärzel et al., 2006). Our conclusions support organic breeding strategies combining low-input and organic stages developed recently by winter wheat breeders at INRA in France and by Saatzucht Donau in Austria (Löschenberger et al., 2008).

Löschenberger F., Fleck A., Grausgruber H., Hetzendorfer H., Hof G., Lafferty J., Marn M., Neumayer A., Pfaffinger G. & Birschitzky J. (2008). Breeding for organic agriculture: the example of winter wheat in Austria. *Euphytica*, 163: 469-480.

Schwärzel R., Levy L., Menzi M., Anders M., Winzeler H. & Dörnte J. (2006). Comparaison de deux réseaux d'essais variétaux de blé d'automne en cultures biologique et extensive. *Revue Suisse d'Agriculture* 38: 35-40.

Organic seeds and plant breeding: the stakeholder's uses and expectations

Frédéric Rey[1], *Véronique Chable*[2], *Riccardo Bocci*[3], *Hans Jürgen Reents*[4]

[1]*ITAB, Institut Technique de l'Agriculture Biologique, France, frederic.rey@itab.asso.fr,*
[2]*INRA, Institut National de la Recherche Agronomique, SAD Paysage Rennes, France, Veronique.Chable@rennes.inra.fr,*
[3]*AIAB, Associazione Italiana Agricoltura Biologica, Italy, r.bocci@aiab.it,*
[4]*Lehrstuhl für Ökologischen Landbau und Pflanzenbausysteme Alte Akademie , Freising, Germany, reents@wzw.tum.de*

There is a lack of varieties adapted to all the different kinds of organic agricultural systems. Within the framework of the European project Solibam (Strategies for Organic and Low Input Breeding and Management), a study was undertaken to determine the important traits specific to organic and low input farming for cereals including wheat, and for horticultural crops including tomatoes. This study, based on surveys, also aims to describe which varieties farmers grow, why, and the organic stakeholders' expectations in plant breeding over a wide range of different agro climatic conditions in Europe. The result of this study provides data where existing published information is scarce, for example: identification of the varieties currently grown by the organic producers; reasons for their variety choice; producers' expectations for organic varieties. Most of the published papers dealing with organic plant breeding programs concern cereal crops (Lammerts et al 2008, Wolfe et al 2008, Goldringer et al 2010). Papers on horticultural crops are limited and those on organic stakeholders expectations are even fewer. The recent State of Organic Seed report (USA) is an exception which can nevertheless be highlighted; based on stakeholder surveys it analyses the challenges and opportunities in building the organic seed sector (Dillon & Hubbard 2011).

In our study, as a first step, a qualitative survey (with open questions) was carried out in France, Germany and Italy. This work aimed to identify the key research questions/hypotheses in an European perspective: useful plant traits for organic and Low Input (LI) agriculture may differ considerably from one country to another depending on the agroecological conditions and on the market, e.g. two main market categories have been clearly identified from the French stakeholders' answers. These categories and results fit with the hypothesis that the market is a significant factor influencing the choice of seeds and varieties. Expectations and practices of producers selling on a local market (i.e. direct sale) differ radically from those of producers selling to large retailers.

References

Dillon M, Hubbard K (2011): State of organic seed. Organic seed alliance report http://www.seedalliance.org/Publications, (accessed 2011-06-01).

Goldringer I., Dawson J., Vettoretti A., Rey F. (2010): Breeding for resilience: a strategy for organic and low-input farming systems?. Eucarpia 2nd conference of the "Organic and Low-Input" Section, 1-3 Dec. 2010, Paris, France http://orgprints.org/18171/1/Breeding_for_resilience%2DBook_of_abstracts.pdf, (accessed 2011-06-01).

Lammerts E., Ostegard H., Goldringer I., Scholten O. (2008): Plant breeding for organic and sustainable, low input agriculture: dealing with genotype-environment interactions, Euphytica, Vol. 163, Number 3, 546 p.

Wolfe MS, Baresel JP, Desclaux D, Goldringer I, Hoad S, Kovacs G, Löschenberger F, Miedaner T, Østergård H, Lammerts Van Bueren ET. (2008): Developments in breeding cereals for organic agriculture in Europe. Euphytica 163:323–346

Experiences from organic maize breeding and prospects of coevolutionary breeding

Walter Schmidt

KWS SAAT AG, Grimsehlstr. 31, 37574 Einbeck, Germany, walter.schmidt@kws.com

Objectives of organic maize breeding at KWS

KWS SAAT AG has the ambition to offer each farmer varieties which are optimized for his very individual purpose and way of farming: for conventional as well as organic farming.

For this purpose, KWS has been developing during the past ten years not only maize varieties under conventional cropping conditions, but at the same time as well under the conditions of organic farming. Therefore, KWS started with its own experimental station in the year 2002 at the KWS Klostergut Wiebrechtshausen, a farm leased from the charitable foundation “Klosterkammer Hannover”.

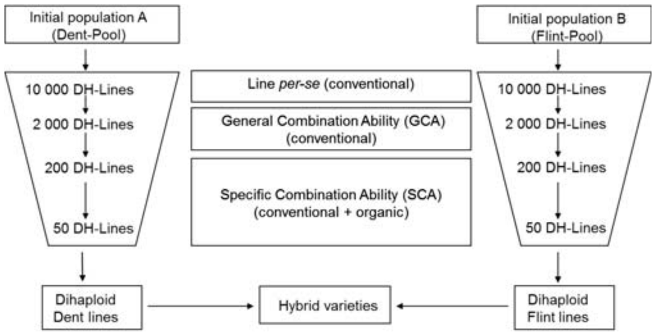
After ten years of experiences acquired in the development of maize varieties for organic farming, we were able to ascertain that organic breeding not only leads to the development of improved varieties for organic farming, but as well to varieties with a higher yield stability for conventional farming. Moreover, organic breeding aims at developing varieties offering the opportunity to lead the entire agriculture to a more ecological approach. This implies for instance maize varieties for dual use, of which stover is still able to be used for silage at grain maturity, as well as maize varieties which are suitable for intercropping with leguminosae, especially with climbing beans. Maize varieties for dual use should be able to resolve the famous conflict between the use for bioenergy production and fodder production, and the conflict which is to be found in organic farming and developing countries with less milk performance: the conflict between food and feed („Feed no Food!“). Maize varieties which are suitable for intercropping with leguminosae may offer an opportunity to conventional farming to come closer to ecological goals like agro-biodiversity, nitrogen fixation, and reduction of soybean imports.

Optimizing breeding strategies for the development of organic varieties making a maximum use of selection gains achieved in conventional maize breeding

During the past years, KWS has been carrying out quite a number of scientific projects in cooperation with the universities of Hohenheim (Prof. Geiger), Göttingen (Prof. Becker, Prof. Rauber), and Wageningen (Prof. Lammerts van Bueren), with the HfWU Nürtingen (Prof. Pekrun), and with the FIBL (Dr. Messmer), to optimize organic breeding.

Within these ten years of projects, the calculations necessary to optimize breeding strategies, and simultaneously the experiences acquired made KWS develop the breeding scheme shown in illustration 1: The organic breeding program picks up lines developed in conventional breeding programs at a moment, where conventional breeding already has done a large part of pre-selection works for organic breeding (lines-*per-se* and GCA-test), while there is still enough variability regarding suitability for organic farming. This is the moment where the lines enter the stage of the SCA-tests.

During this stage, KWS tests the lines under organic conditions at three to four sites in order to identify the ideal lines suitable as well for hybrid development as for reciprocal recurrent selection (RRS). Only the lines with excellent results in both cropping systems are selected and recombined. The conventional test mainly increases the maximum yield potential of the breeding material, while the organic test improves its suitability for organic production, and its yield stability. As a new RRS-cycle is not started before having identified suitability for organic cropping, such strategy not only improves hybrids regarding their suitability for organic production, but as well the basic populations on which hybrid breeding is based.



Combination of conventional and organic varietal development in the German maize breeding program of KWS

However, this strategy has a bottleneck: It is difficult to select for competitiveness against weeds, as on organically farmed trial fields, weeds usually do not appear evenly distributed, but more spot-like. By selecting for competitiveness by means of an underseed of rye, buckwheat, and chicory, we strive for reviving the maize's competitiveness and with this its suitability for intercropping (see poster presentation of STEVER et al. 2013).

New breeding approach: Coevolutionary plant breeding to reach ecological goals

The strong point of maize is its performance potential. As maize breeding has been able to triple grain production and double silage production within the past fifty years, the German cropping surface now reaches 2.5 million hectares. Seen from the ecological point of view, this is increasingly criticized. However, it would not be optimal to renounce to the maize's performance potential in our current crop rotations. Therefore, a most promising solution would be to grow maize the way it has been cropped in the countries where it came from, which is, intercropping together with a different crop. First results have shown that intercropping of maize and climbing beans could be a most attractive cropping system (PEKRUN et al., 2013). At KWS, we have already started improving maize varieties regarding their suitability for intercropping with climbing beans (see poster presentation of HOPPE et al. 2013). The results of the year 2012 showed that this cropping system will enormously benefit, if climbing bean varieties are as well optimized in breeding for their suitability for intercropping. First screening trials proved that variation in runner beans is at least as large as in maize.

Once the best combining maize and climbing bean varieties for intercropping are identified, the next logical step will be to achieve a coevolutionary development of both crops towards each other. If the future would see as well leguminosae growing on a large part of today's 2.5 million hectares of maize cropping surface, this would constitute the most important step conceivable by now, towards more ecology in agriculture.

Hoppe, C., Schmidt, W. & Becker, H.C. (2013). Improving energy maize with specific adaptation to intercropping with climbing beans. *Poster EUCARPIA conference*

Pekrun, C., Hubert, S., Schmidt, W. (2010). Mais/Stangenbohnen-Gemenge. Biogassubstrat mit Zukunft? *Mais*, 1/2010: 30-32.

Stever, M., Schmidt, W., Burger, H. & Becker, H.C. (2013): Development of maize hybrids with high weed tolerance for organic farming systems. *Poster EUCARPIA conference*

Oral Contributions

Session 3

Genetic and agronomic advances in nutrient use efficiency in four major crops: results from the NUE-CROPS project

The Interaction of Nitrogen with Yield in Wheat

Peter Werner, Claire Fremann, Guillaume Barral-Baron, Bill Thomas and Luke Ramsay

Peter.Werner@kws.com

The small grain cereals work package of the European funded project FP7 NUE-Crops (SP1) is investigating the genetic interaction of nitrogen inputs across a diverse range of European barley and wheat varieties. The studies in barley are reaching completion and the successful approaches and knowledge gained are, where possible, now being applied to wheat. A panel of 144 winter wheat varieties have been tested in field trials conducted in 2011/12 and 2012/13. We present preliminary results from these trials which were conducted at three sites (2 in the UK and one in Germany) where 3 rates of applied nitrogen were used. Grab sample methods were used to enable the partitioning of the main yield and nitrogen components. Highly significant differences between genotypes were observed for most traits at most sites. Significant interactions of genotype with applied nitrogen were seen for yield, components of yield and grain N%. The panel of lines have been genotyped with the 90K iSelect chip and preliminary association mapping results are presented. We discuss further activities of the project that will broaden knowledge of variability and control of NUE in wheat in relation to yield and yield components.

Improvement of Nitrogen-Use Efficiency in Maize

Thomas Presterl[1], Therese Welz[1], Milena Ouzunova[1], Nikolai K. Christov[2], Guohua Mi[3], Elena Pestsova[4], Christian Wever[4], Peter Westhoff[4]

[1]*KWS SAAT AG, 37555 Einbeck, Germany,* thomas.presterl@kws.com, [2]*Agrobioinstitute, 8 Dragan Tsankov blvd., 1164 Sofia, Bulgaria,* [3]*China Agricultural University, College of Resources and Environmental Sciences, Department of Plant Nutrition, Beijing, 100193, China,* [4]*Heinrich-Heine-Universität Düsseldorf, Entwicklungs- und Molekularbiologie der Pflanzen, Universitätsstraße 1, 40225 Düsseldorf*

Maize (Zea mays L.) cultivars with improved nitrogen-use efficiency (Nit-UE) may significantly contribute to the economics and sustainability of farming under low soil N availability. Published studies using European and Chinese maize populations clearly showed that selection for increased maize yields at reduced N supply is possible. The objective of this work-package of the NUE-CROPS project was to evaluate different strategies to optimize breeding for improved Nit-UE.

The identification of novel quantitative trait loci (QTL) for Nit-UE was conducted in field experiments in China and Europe using four mapping populations. Major QTL for grain yield under stress conditions were detected in these populations and will be used for marker assisted improvement of Nit-UE in maize. The populations considered different approaches for the utilization of genetic resources to improve Nit-UE. South-American materials and a population generated from a cross of a line obtained by chemical mutagenesis with its initial elite temperate breeding line were evaluated in South-Europe. A set of double haploid lines from Flint maize landraces was used in North-Europe. The Flint lines did not show any advantage in Nit-UE compared to elite checks, while the South-American and the mutant x initial line population proved to be promising genetic resources for Nit-UE.

In parallel two of the QTL mapping populations were analysed under controlled conditions for their root phenotypes at seedling stage. Several stable QTL were detected for root morphology traits and some of the identified QTL for root traits have been found to coincide with the QTL for yield detected under field conditions. This indicates that morphological differences in root architecture might, at least in part, be responsible for the observed differences in Nit-UE.

Beside the QTL targeted approach also genome wide selection with a large set of marker was evaluated using elite breeding materials from Germany and South-East Europe. For grain yield predictive abilities from genome wide selection were between 35 and 49% with no clear trend regarding the different levels of environmental stress. The correlation between the genomic estimated breeding values at stress with the actual phenotypic values was r=0.75, indicating that genome wide selection will be a promising approach to improve the quantitative genetic basis of Nit-UE in maize.

Acknowledgement

The authors gratefully acknowledge funding from the European Community financial participation under the Seventh Framework Programme for Research, Technological Development and Demonstration Activities, for the Integrated Project NUE-CROPS FP7-CP-IP 222645. The views expressed in this publication are the sole responsibility of the author(s) and do not necessarily reflect the views of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use which might be made of the information contained herein.

Breeding strategies to improve nitrogen use efficency (Nit-UE) in oilseed rape

J. Keurentjes[1], N. Erol-Oztolan[1] , F.Breuer[2], A.Gertz[2], S.Miersch[3], H.C.Becker[3]

[1]WU Plant Sciences, Laboratory of Genetics, Droevendaalsesteeg 1,6708PB Wageningen, The Netherlands; [2]KWS SAAT AG, Grimsehlstraße 31, 37574 Einbeck, Germany; [3]Department of Crop Sciences, Georg-August-Universität Göttingen, Von-Siebold-Str. 8, 37075 Göttingen, Germany, hbecker1@uni-goettingen.de

In Europe, oilseed rape is traditionally produced with high N-fertiliser inputs to obtain maximum grain yields. This results in significant levels of nitrate leaching into the groundwater after harvest. *B. napus* is an allotetraploid species with often a large number of gene copies and a very complex pattern of inheritance, which makes the identification of QTL extremely difficult. In contrast, genetics in the diploid model species *Arabidopsis thaliana* and the diploid crop species *B. rapa* is more straightforward. The main approach is therefore to increase our knowledge on Nit-UE in *Arabidopsis thaliana* and *B. rapa* and to then transfer and apply this in *B. napus*. In this contribution we report results on *A. thaliana* and on *B napus*. Results on *B. rapa* are presented by Ling Meng et al. in this conference booklet (O 3-7).

Arabidopsis thaliana

We study this species to identify genes involved in Nit-UE, which can be used as syntenic markers for breeding strategies of target *B. napus* and *B. rapa*. We used HapMap population (a natural population consisting of 350 accessions collected from around the world and genotyped densely for 250,000 SNPs) and genome-wide association (GWA) mapping. The population screening is done in a climate chamber; plants are grown until flowering under optimal (control) and sub-optimal (N deficiency) growth conditions. Chlorophyll fluorescence is measured using high-throughput phenotyping platform. Different genotypes show different responses under N-deficient condition, which indicates natural variation in Nit-UE related genes. So far 10 candidate genes, significantly associated with fresh and dry weights, Nit-UE, N usage index (Nit-UI), water content, chlorophyll fluorescence, and N concentration have been identified. As an additional confirmation, QTL mapping is conducted in the RIL population (F8) of two extreme genotypes from HapMap population. Five QTL co-localized with the candidate genes identified in association mapping. Genotypes, which show extreme phenotypes, have been determined and grown under optimal and sub-optimal conditions. Differential gene expression between extreme genotypes will be checked using qRT-PCR

Brassica napus

One approach to increase Nit-UE is to improve the harvest index (HI) by using dwarf genes. From a cross between a normal growing resynthesized line and a dwarf form of a common cultivar a DH population was developed segregating into dwarf and normal growing lines. All DH lines were crossed to a normal growing, male sterile tester to produce test cross hybrids segregating into semi-dwarf and normal growing genotypes. In two years 108 TC (54 normal, 54 semi-dwarf genotypes) were grown at two locations with two N levels (no fertilization and optimal N fertilization). All DH-lines were genotyped with SSR and SNP markers to construct a linkage map and perform a QTL analysis. At both N levels the semi-dwarf types had a higher HI and produced significantly higher seed yields compared to the normal type lines. The localization of QTL for grain yield, straw yield and HI at the position of the dwarf gene confirmed these results. For details see contribution of Miersch and Becker (P 8) in this Conference Booklet.

The authors gratefully acknowledge funding from the European Community for the integrated Project NUE-CROPS FP7-CP-IP 222645.

Diversity of crop development traits and nitrogen use efficiency among potato varieties grown under contrasting nitrogen regimes.

C.A. Ospina[1,2], *E.T. Lammerts van Bueren*[2], *J.J.H.M. Allefs*[3]; *P.E.L. van der Putten*[1]; *G. van der Linden*[2] *and P.C. Struik*[1]

[1]*Centre for Crop Systems Analysis, Wageningen University, Wageningen, The Netherlands, cesarandres.ospinanieto@wur.nl;* [2]*Wageningen UR Plant Breeding, Wageningen, The Netherlands,* [3]*Agrico research, Bant, The Netherlands.*

For food security crops such as potato, nitrogen (N) fertilization has tremendous agronomic, economic and environmental impacts. The crop requires large quantities of nitrogen to perform well, but due to the small and shallow root system much of this nitrogen is wasted. Regulations like the EU nitrate directive (91/767/EEC) have induced changes in crop management and breeding aims to reduce N input, by improving nitrogen use efficiency (NUE) and performance under low nitrogen supply. Canopy development is an important factor in N response and NUE of the crop. In this study we aimed to identify phenotypic variation for NUE, its main underlying factors, and its relation with ecophysiological parameters describing canopy development under high and low N input. For this purpose, a set of 186 diverse potato genotypes was used that included modern high-performance varieties as well as some exotic potato genotypes from Europe.

In 2009 and 2010 the set of genotypes was grown under two N levels (75 and 180 kg N/ha) at the breeding station of Agrico Research (Bant, Noordoostpolder, The Netherlands). Canopy development (CDv) was assessed weekly as the percentage of soil covered by green potato leaves (%SC) throughout the growing season and data were analysed based on a physiological model of CDv. Days after emergence were converted into thermal days to describe CDv as a function of temperature, using the beta function and the three cardinal temperatures for potato. Relevant curve fit parameters estimated from the model for each individual genotype showed significant differences between nitrogen levels. Only the thermal time required to reach the maximum soil cover (Vmax), increased by low input. The other parameters were decreased, especially Vmax and the period over which it was maintained. N levels affected tuber dry matter yield, size or weight distribution, N content and N uptake but not the dry matter percentage. The total area under the curve of %SC was highly correlated with yield in both years. In conclusion, genotypes performing well under low N also perform well under high N. There was a large variation in components of NUE between genotypes, and maturity type partially explained this variation. Finally, parameters of the CDv model captured this variation and showed the N effects on light interception and its correlation with yield. An association mapping analysis will follow to identify genetic factors related with NUE in potato.

Getting to the Root of Phosphorus Use Efficiency in Potato

Timothy S. George, *Jayne Davies, Christine A. Hackett, Pete Hedley, Gavin Ramsay, Nithya K. Subramanian, Jacqueline A. Thompson, Gladys Wright, Philip J. White*

The James Hutton Institute, Invergowrie, Dundee DD2 5DA, UK; philip.white@hutton.ac.uk

Introduction

Potato (*Solanum tuberosum* L.) requires large amounts of phosphorus (P) fertiliser, which incurs both financial and environmental costs. In the interests of sustainable crop production, it is important to reduce these P-fertiliser applications. This can be achieved by improving management practices and developing genotypes with greater phosphorus use efficiency (PUE).

Materials and Methods

Genotypic variation in PUE was assessed in a core collection of 23 tetraploid (tuberosum) genotypes plus 9 phureja genotypes and in a tetraploid genetic mapping population (12601ab1 x Stirling). Both were grown in the field in two consecutive years both with and without the application of P fertiliser. Phosphorus concentrations in diagnostic leaves ($[P]_{leaf}$) were determined at canopy closure. Yields and concentrations of mineral elements in tubers were determined at commercial maturity. Quantitative trait loci (QTL) for these traits were determined in the mapping population. Eight genotypes with contrasting agronomic PUE, P acquisition efficiency (PUpE) and physiological P utilisation efficiency (PUtE) were identified from the core collection for subsequent physiological and genetic studies. These genotypes were subsequently grown in the field, in pots in the glasshouse and in hydroponics under two rates of P-supply.

Results and Discussion

Consistent QTL affecting yield, $[P]_{leaf}$ and PUtE were identified. It was observed that QTL for PUtE and tuber yield often co-locate, and that major QTL for tuber yield, $[P]_{leaf}$ and PUtE on Stirling Linkage Group V at 68 cM co-locate with a QTL explaining about half the phenotypic variation in crop maturity. Among the eight selected genotypes, there were strong positive relationships between root mass at establishment and (a) shoot mass at establishment and (b) early tuber biomass accumulation in the field. However, the latter relationship became weaker during the season, which is consistent with the hypothesis that early root vigour increases tuber yields indirectly by accelerating canopy development. There was a strong positive relationship between root mass at establishment and plant P content, but this relationship again became weaker during the season. Studies in the glasshouse confirmed that root system parameters correlated well with P uptake and shoot growth, and yield in the field. When grown hydroponically, the expression of many genes differed between roots of plants grown with 25 and 250 µM P. The expression of more genes was affected by P supply in roots of low-yielding genotypes than in roots of high-yielding genotypes, which suggests that the lower-yielding genotypes experienced greater P-starvation stress than higher-yielding genotypes. Seventy three genes differed in their expression between roots of P-replete and P-starved plants of all genotypes. These genes represent a common transcriptional response to P-starvation. The expression of 126 genes is correlated with high yields at low P inputs, and these provide candidates for understanding the differences in yield responses of potato genotypes to P-supply. These data can be used to identify candidate genes controlling PUE in potato and the development of molecular markers for breeding for PUE in this crop.

Model simulation of cropping system NUE as affected by genotype variation in NUE based on different plant traits

Kristian Thorup-Kristensen, Dorte Bodin Dresbøll

University of Copenhagen, Department of Plant and Environmental Sciences, Højbakkegård Allé 13, 2630 Taastrup, DK; dbdr@life.ku.dk

The benefits of improving NUE in crops can be measured on a crop, as increased yield or N content per unit N supplied or taken up, depending on how NUE is defined. However, what we want is improved NUE of the cropping systems, and it is less clear how the improvement of NUE of one crop will affect the succeeding crops and the NUE of the crop rotation. The use of model simulations will facilitate impact assessments and contribute to our understanding of the effects on the system as such.

Based on experimental results from the 'NUE crops' project we develop improved model algorithms and parameterization for different types of improved NUE, e.g. through higher N harvest index, higher dry matter production per unit N in the crop, reduced litter loss or improved root growth. The different forms of improved NUE have different effects on the cropping system. In our field study we focus especially on effects on litter loss rate and root growth. Reduced litter loss and increased root growth may both lead to increased harvest of N with the crop, but the "origin" of this N will be different.

With reduced leaf litter loss, more N becomes available for yield production because less is built into soil organic matter via leaf litter loss. This will subsequently reduce N mineralization in the soil, reducing N availability for succeeding crops as well as the risk of N leaching loss in the following years. If NUE is improved through deeper rooting, the extra N for yield will come from deep soil layers, and increased N uptake from deep soil layers will very directly reduce N leaching loss from the soil. In this situation, N harvest in the crop can be increased with little risk of reducing N supply for future crops, environmental loss is reduced instead.

Simulations also show that the effect of genotypes with improved NUE depend on environment and crop management. This is true both for the effect seen in the improved crop itself and when its effect is analyzed for a whole crop system. If the N supply compared to crop demand is already high, neither deeper rooting nor reduced leaf litter loss may improve the NUE actually achieved. Reduced leaf litter loss may even directly increase subsequent N leaching loss, as less N is built into soil organic matter but left as inorganic N in the soil. The environmental conditions, subsequent crop choice and management will all affect the fate of the N left by the crops in the soil, and whether this will contribute mainly to leaching loss or be used for production in later crops.

All in all, the simulations illustrate the concept of NUE as an example of interactions between genotype, environment and crop management (G×E×M), where the effect of any single approach can only be understood through its interactions with other factors.

QTL mapping of NUE in *Brassica rapa* and Maize

Lin Meng[1], Bo Liu[1], Wen Zhai[1], Jianming Ding[1], Niaz Ahmad Wahocho[1], Guohua Mi[2], Jian Wu[1]

[1] Institute of Vegetables and Flowers, Chinese Academy of Agricultural Sciences, Beijing 100081, China, miguohua@cau.edu.cn; wujian@caas.cn, [2] College of Resources and Environmental Sciences, China Agricultural University, Beijing 100193, China;

Brassica rapa comprises many kinds of vegetables, both of which cultivation area and production are the highest among vegetables in China.Massive quantity of nitrogen is applied to *B. rapa* crops every year. To develop *B. rapa* cultivars with better nitrogen use efficiency (NUE), it is prerequisite to dissect the mechanism responsible for this ability.

Water and nitrogen limitation are the major issues faced in maize production around the world. QTL-based improvement is a promising approach to breed maize cultivars tolerant to low N and water stress. Furthermore, because lateral roots are the major organs for water and nutrient uptake, it is important to find the QTLs controlling maize lateral roots growth.

Materials and Methods

160 *B. rapa* accessions were genotyped through SLAF-seq technology (Sun et al., 2013) and phenotyped in both open field and greenhouse. The genotype data set was generated by identifying SNP and small InDel sites (MAF > 0.05). Association analysis was conducted using MLM by the software TASSEL (V3.0) (Bradbury et al., 2007). A *B. rapa* RILs population containing 149 F7 lines and a DH population containing 104 lines were used to map QTL of morphological traits of plant growing in composts or in hydroponic culture with 3 mM and 10 mM N supplements. A maize RILs population derived from the parents of Ye478, a large-root inbred line, and Wu312, a small-root inbred line, was used for mapping QTLs associated with yield and agronomic traits in maize under various water and nitrogen input, as well as QTLs related to root traits at seedling stage under three batches of hydroponics and two batches of paper roll tests.

Results

Association mapping in B. rapa: A total of 58 and 90 association signals were identified in the experiments of open field and greenhouse, respectively. Whole genome LD decay rates of *B. rapa* were computed at approximately 10 kb which is similar to result in *A. thaliana* (Kim et al., 2007). Using 10 kb upstream and downstream of these association loci, candidate causal genes were identified based on syntenic relationship to *A. thaliana*.

QTL mapping in B. rapa: In total 30 QTLs were identified for RIL population in the experiment conducted in spring of 2011, while 42 QTLs were identified in the experiment in autumn of 2012. For the DH population, totally 15 QTLs were identified for plants grown in compost, while there were six QTLs were identified in hydroponic experiment.

QTL mapping in Maize: From the experiment under various water and nitrogen input, five important QTLs were identified, including QTL at bin 1.11(ASI at normal condition), QTL at bin 2.06/2.07 (grain yield at low N and water stress), QTL at bin 3.04 (grain yield at water stress), QTL at bin 4.01(grain yield and straw yield) and QTL at bin 3.08/3.09 (kernel weight). From the experiment on lateral root growth, three stable QTLs were identified, including QTL at bin1.06 (lateral root density on primary root); QTL at bin 3.04 (seminal root number) and QTL at bin 3.04 (root dry weight). At bin 3.04, 11 QTLs were detected, indicating that bin 3.04 may play an important role in maize root growth and development at seedling stage.

References

Sun X, Liu D, Zhang X, Li W, Liu H, Hong W, Jiang C, Ma C, Zeng H, Xun C, Song J, Huang L, Wang C, Shi J, Wang R, Zheng X, Lu C, Wang X, Zheng H. (2013) SLAF-Seq: an efficient method of large-scale de novo SNP discovery and genotyping using high throughput sequencing. PlOS ONE, 8(3): e58700

Bradbury, P.J., Zhang, Z., Kroon, D.E., Casstevens, T.M., Ramdoss, Y. and Buckler, E.S. (2007) TASSEL: software for association mapping of complex traits in diverse samples. Bioinformatics, 23, 2633-2635

Kim, S., Plagnol, V., Hu, T.T., Toomajian, C., Clark, R.M., Ossowski, S., Ecker, J.R., Weigel, D. and Nordborg, M. (2007) Recombination and linkage disequilibrium in Arabidopsis thaliana. Nat Genet, 39, 1151-1155

Poster Abstracts

Estimation of quantitative genetic parameters for grain yield and quality in winter wheat under optimal and reduced nitrogen fertilization

Hrvoje Šarčević[1], Katarina Jukić[2], Ivica Ikić[2], Ana Lovrić[1], Marija Pecina[1], Marijana Barić[1]

[1]University of Zagreb, Faculty of Agriculture, Svetošimunska 25, 10000 Zagreb, Croatia
[2]Bc Institute for Breeding and Production of Field Crops, Dugoselska 7, 10370 Dugo Selo, Croatia; hsarcevic@agr.hr

Introduction

Information on the performance of wheat genotypes under a range of nitrogen (N) levels in multi-environment tests is expected to be helpful in identification of genotypes better adapted to low N environments. The objectives of the present study were to (1) investigate the effect of two N levels on grain yield and grain quality traits, and (2) estimate variance components and heritability for these traits under high and low N levels in a selection of winter wheat varieties differing in yield potential and grain quality.

Material and methods

Field trials including 19 winter wheat varieties were conducted during three successive growing seasons under optimal (180kg Nha^{-1}) and reduced (80kg Nha^{-1}) N fertilization in total of eight environments (location-year combinations). Other cultural practices including fertilization with phosphorus and potassium were equal for both fertilization levels. Mean values, components of variance and heritability were estimated under each N level as well as across N levels for grain yield (GY), grain N yield (GNY), grain quality traits such as grain protein content (GPC), Zeleny sedimentation value (SED), wet gluten content (WGC), gluten index (GI) and falling number (FN) as well as for rheological dough properties.

Results and discussion

Mean GY across environments was significantly lower (10.3%) under reduced than under optimal N fertilization with the reduction ranging from 4 to 36% for individual environments. Reduced fertilization also significantly decreased mean GNY (21.5%), GPC (13.3%), SED (27%), WGC (19%), and FN (4.6%), and significantly increased mean GI (7%). All mean values for rheological dough properties were more favourable under optimal N fertilization as compared to the reduced N fertilization. In the analyses across N levels and environments, genotypic variance was significant for all traits and was larger than the genotype x environment variance except for GY and FN. Genotype x N level variance was not significant for GY and FN. For all other grain quality traits as well as for most rheological dough properties genotype x N level variance was significant but with relatively low contribution to the total phenotypic variance. A high phenotypic correlation between the two N levels were observed for GY (0.94**) and GPC (0.92**). Heritability estimates for GY, GNY, and some rheological dough properties were larger under optimal than reduced N fertilization but comparable for all other traits. Stronger negative correlation was observed between grain yield and protein content under reduced (r=-0.72**) than under optimal (r=-0.56*) N fertilization. The results of the present study showed that testing genotypes under optimal N fertilization can give good prediction of their performances in low N environments. In order to cost-effective use of resources selection of superior wheat genotypes, aimed at growing under both high and low N conditions, can be conducted through conventional breeding programs using optimal N fertilization. To check for specific adaptation of a genotype to N stress conditions, a range of N levels can be applied in the final test including smaller number of previously selected genotypes.

Characterization of nitrogen use efficiency in a Hungarian winter wheat collection

István Monostori, Tamás Árendás, Attila Vágújfalvi, Fruzsina Szira

Agricultural Institute, Centre for Agricultural Research, Hungarian Academy of Sciences, Brunszvik u. 2., H-2462 Martonvásár, Hungary, szira.fruzsina@agrar.mta.hu

Introduction

Winter wheat is one of the main cereals and has great importance in human nutrition. Economic cultivation of cereals without appropriate fertilization management is not realistic; therefore identification of varieties with better nitrogen (N) uptake and N utilization efficiency is a very important topic. Additionally, reduced N fertilization rate can also help to decrease the environmental and groundwater pollution. The main objective of this study is to investigate and characterize the N-use efficiency in a winter wheat collection that consists mainly Hungarian winter wheat varieties. Our result may promote more rational and environmentally friendlier fertilization management in Hungary. The identified lines and varieties with good N use efficiency can also be used directly in marker-assisted selection system or might be applied as a crossing partner.

Material and methods

96 winter wheat lines were investigated under field condition in 2013 using two N supplies. An extensive (0 kg/ha) and an intensive (140 kg/ha) N level was adjusted. This test will be replicated in the next two years. The wheat collection was evaluated for agronomically important characters (grain yield, 1000 grain weight, plant height, heading time, biomass and harvest-index) and N-use related traits (N use efficiency, N uptake efficiency, N utilization efficiency). The N content of grain and biomass samples were determined by a N analyzer device (Elementar Rapid N III), using the Dumas combustion method. Statistical analysis was performed using SPSS 16.0 for Windows.

Results and discussion

This is the first year of a four year long project, so our first results will be presented in the final abstract.

This work was supported by the Hungarian Research Fund (OTKA K101794).

Spring barley traits associated to nitrogen use efficiency under organic conditions

Aina Kokare[1], Linda Legzdina[1], Indra Beinarovica[1], Mara Bleidere[2] , Zinta Gaile[3]

[1]State Priekuli Plant Breeding Institute, Zinatnes street 1a, Priekuli LV-4126, Latvia, aina.kokare@priekuliselekcija.lv
[2]State Stende Cereal Breeding Institute, Dizzemes, Dizstende, Latvia
[3] Latvia University of Agriculture, Jelgava, Latvia

Introduction

The readily available amount of nutrients is often lower in organic than in conventional farming system. Nutrient use efficiency is a very complex trait and depends on the particular mineral nutrient, on crop species and genotype, and on the environmental conditions. Breeders are interested to identify also the morphological and physiological plant traits that are related to nutrient use efficiency and which allow selection in early generations. Protein yield can be used as one of indirect traits associated with nitrogen use efficiency under organic crop management (Löschenberger et al. (2008). The aim of this study was to determine how barley genotypes grown under distinct organic conditions differ in protein yield and whether protein yield is related to some definite traits and nitrogen use efficiency.

Material and methods

Field trials under organic management in three locations in Latvia were carried out during 2010 - 2012. 21 spring barley genotypes including various cultivars and breeding lines were used in the investigation. Yield and grain protein content were determined and protein yield was calculated. Nitrogen use efficiency was estimated according to Moll et al. (1982). Plant height at the beginning of stem elongation stage and at harvest, length of growth period from sowing to heading and from sowing to ripening were determined.

Results and discussion

Positive correlation was found between nitrogen use efficiency and protein yield. Protein yield mostly depended on environment: growing location and meteorological conditions of the particular year. Plant height at beginning of stem elongation stage correlated positively (r= 0.19 – 0.68) with protein yield under most growing locations, but positive correlation with plant height at harvest was found only in one growing location. Negative correlation (r =-0.17 – (-0.66)) between protein yield and length of growth period from sowing to heading was observed, indicating that genotypes with earlier heading had tendency to have higher protein yield. Inconsistent relation was found between protein yield and length of growth period from sowing to ripening. We can conclude that during the selection in early generations for nitrogen use efficiency for organic farming attention should be paid to genotypes with taller plants in first half of plant development and earlier heading time; however, those traits should be taken into account in connection with plant productivity and grain yield.

References

Moll, R.H., Kamprath, E.J., Jackson, W.A. (1982). Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. *Agronomy Journal,* 74:562-564.

Löschenberger F, Fleck A, Grausgruber H, Hetzendorfer H, Hof G, Lafferty J, Marn M, Neumayer A, Pfaffinger G, Birschitzky J (2008) Breeding for organic agriculture: the example of winter wheat in Austria. *Euphytica* 163: 469–480

Selection strategy for nitrogen efficient potato cultivars

Marjolein Tiemens-Hulscher [1], Edith T. Lammerts van Bueren [1,2], Paul C. Struik[3]

[1] Louis Bolk Institute, Hoofdstraat 24, 3972 LA Driebergen, the Netherlands, e.lammerts@louisbollk.nl
[2] Laboratory of Plant Breeding, Wageningen University, Wageningen, the Netherlands
[3] Centre for Crop Systems Analysis, Wageningen University, Wageningen, the Netherlands

Sustainable agriculture requires potato cultivars with reliable and stable yields under relatively low nitrogen input. Nitrogen efficiency is a complex trait; it is the resultant of many different crop characteristics. We defined nitrogen efficiency as the ability of a potato variety to produce a reliable yield when 100 – 150 kg N is available per ha and the crop cycle lasts from mid-April to approximately the third week of July (90 – 95 days). We examined which crop traits related to nitrogen efficiency are suitable selection criteria when crops are grown under such restrictions.

From 2008 to 2011 eight trials were conducted at two locations (organic and conventional) with different nitrogen rates. We analysed nitrogen efficiency of 18 cultivars and the crop traits associated. Within a growth period of 90 – 95 days, late cultivars accumulated more nitrogen than early cultivars. However, the harvest index of early cultivars after 90 – 95 days was higher than that of late cultivars, resulting in about the same amount of nitrogen in the tubers for early, mid-early and late cultivars. The mid-early cultivars converted this nitrogen more efficiently into tuber dry matter than early and late cultivars and therefore gave the highest dry matter yield per ha. We focused mainly on the parameters of the ground cover progress curve (GCPC). The correlations between the curve-fit parameters and the dry matter production varied considerably over years, locations and cultivars. The curve-fit parameters maximum ground cover (Vx), the period of maximum ground cover (T2 – T1) and the Area Under the Ground Cover Progress Curve (AUGCPC) were most consistently correlated with yield. In retrospect, if cultivars with the highest Vx, the longest T2 – T1 or the highest AUGCPC in all year × location combinations had been chosen under the lowest nitrogen level (total N availability of approx. 90 – 100 kg N/ha), 70% of the most productive cultivars would have been selected. With selection under the highest nitrogen level (total N availability of approx. 300 kg N/ha) this percentage would have been much lower. The curve-fit parameters Vx and T2 – T1 appeared to provide additional, contrasting information. Selection by each of these curve-fit parameters separately resulted in different cultivars being selected. The cultivar effect on the correlation between the curve-fit parameter and dry matter production implies that the selection for high Vx does not always result in the most productive cultivars. However, a high percentage ground cover, also under low nitrogen conditions, is essential for adequate weed control in (organic) potato production.

The organic potato ideotype includes late blight resistance and a yield level with a minimum of 30 Mg/ha within a growing period of 90 – 95 days (from planting), under a nitrogen availability between 100 to 150 kg N/ha, an under-water weight of 340 g per 5 kg sample and a good weed competitiveness. Based on our results we suggest the following strategy to select such organic potato cultivars: 1) Test under field conditions with a nitrogen availability of 100 – 150 kg/ha in the period mid-April to *ca.* third week of July; 2) When selecting in the field for ground cover, use plots of at least 2 ridges and 3 plants long; 3) Select for early tuber set (60 days after planting); 4) Select in the field for late blight resistance; 5) Select for mid-early cultivars (maturity types 6 – 7) and within this selection for: a) cultivars with a high Vx, and b) cultivars with a long T2 – T1, in case the crop is already senescing; 6) Evaluate the harvest after 90 – 95 days after planting and select for cultivars with large tuber number, high yield and an under-water weight of at least 340 g/5 kg sample; 7) Perform this selection for several subsequent years at different locations.

Evaluation of Nitrogen Use Efficiency (NUE) of Hungarian Potato Cultivars

Borbála Hoffmann[1]*, Sándor Hoffmann*[2]*, Szandra Simon*[2]*, Zsolt Polgár*[3]

[1]*Department of Plant Sciences & Biotechnology, Georgikon Faculty, , H-8360, Keszthely, Festetics u. 7. Hungary, hoff-b@georgikon.hu*
[2]*Department of Crop Production & Soil Sciences, Georgikon Faculty, University of Pannonia H-8360, Keszthely, Festetics u. 7. Hungary*
[3] *Potato Research Centre, University of Pannonia, H-8360, Keszthely, Festetics u. 7. Hungary*

Introduction

Crop production is highly dependent on the supply of exogenous nitrogen (N) fertilizers. With increased fertilizer application rate the risks of N losses increase rapidly. Because of the critical role of N rate in achieving economic and environmental objectives, screening for genotypes with better nitrogen use efficiency (NUE) may reduce production costs and at the same time may reduce contamination of the environment by maximizing fertilizer utilization. This study was carried out to evaluate the variation in NUE characteristics of some commercial Hungarian potato cultivars and breeding lines.

Material and methods

The experiment was carried out at UP Georgikon Faculty, Keszthely, on a lessivated brown forest soil with low organic material, medium K- and P content in growing season 2009. The experiment was set up as a split block design with three fertilizer rates as main plots with 3 replications and the cultivars as sub-plots. N was applied in form of ammonium nitrate at rates 0-, 50- and 100 kg N ha^{-1}. 5 varieties: Lorett, Katica, Balatoni Rózsa, White Lady, Hópehely and 3 advanced breeding lines: 00.35, 00.326, 01.536 were examined as well as Pannonia, a newly registered variety released from another breeding company and the standard variety Desiree. 6 plants from each replication were sampled. Fresh and dry weight of shoot and tuber, N content for plant components were determined. Standard commercial practices were used for weed, insect and disease control. No irrigation was applied. NUE was calculated as dry matter production per unit crop N supply which is the result of NUpE x NUtE; NUpE (N uptake efficiency) defined as whole plant N accumulation/crop N supply, NUtE (N utilization efficiency) defined as plant dry matter accumulation/plant N accumulation.

Results and discussion

The results were surprising: the N fertilizer rate used in commercial practices (100 kg N ha^{-1}) had no positive effect on yield except WL and 0035, while the half quantity of the N fertilizer increased yield significantly in case of Katica, Lorett and 01536. The explanation may be the high soil N mineralization caused by the abundant quantity of rain in this growing season. In Hungary potato yield is generally decreased because of water deficiency, but the growing season 2009 was uncommon: after a dry April we had twice as much rain in May and June than the average of 50 years. This may influence the N-utilization of the examined varieties. This assumption is confirmed by the N utilization efficiency results: while NUtE was similar for N-null and N-half treatment, except Hópehely and Pannonia, NUtE in N 100 kg ha^{-1} was significantly lower for all examined varieties.

Acknowledgement:

This project was realized with the support of the project TÁMOP 4.2.4.A/2-11-1-2012- 0001 of the Hungarian Government with the co-funding of the European Social Fund.

Improving Nitrogen Use Efficiency of winter oilseed rape (*Brassica napus L.)* by determining the genetic control of oil yield establishment under nitrogen constraints.

Anne-Sophie Bouchet[1], *Nathalie Nesi*[1], *Christine Bissuel*[1], *Michel Bregeon*[1], *Jérôme Pauquet*[2], *Pierre Georges*[2], *Hélène Navier*[1], *Nicolas Ribière*[2], *Laurent Hanneton*[3], *Mathilde Orsel*[5], *Michel Renard*[1], *Anne Laperche*[1,4]

[1]*UMR 1349 IGEPP INRA, AGROCAMPUS OUEST, Université de Rennes 1, Domaine de la Motte, 35653 le Rheu, France , asbouchet@rennes.inra.fr*
[2]*Biogemma, Chemin de Panedautes, Domaine de Sandreau, 31700 Mondonville, France*
[3]*Limagrain Europe, Ferme de l'Etang, 77390 Verneuil l'Etang, France*
[4] *UEB, Université Européenne de Bretagne*
[5] *UMR IRHS, INRA, AGROCAMPUS OUEST, Université d'Angers, 42 rue Georges Morel, 49071 Beaucouze, France*

Oilseed rape (OSR) is a crop of high economic value grown mainly for its oil used for human consumption and industrial applications. Despite its high nitrogen (N) absorption capacity, OSR has a low N use efficiency (NUE). Therefore, OSR production has a fundamental dependence on N fertilization which causes huge environmental damages. Improving NUE in OSR, and proposing N efficient cultivars, is of major interest. Hence, an extended knowledge of the genetic control of oil yield elaboration under N constraints is needed. The objectives of this work were to determine the genomic regions (QTLs) of OSR associated with oil yield and to assess their stability under various N conditions. Two OSR mapping populations, Aviso x Montego (AM) and Tenor x Express (DK), were tested in two locations (Md and LR) during two growing seasons (2010-2011 and 2011-2012), each time under two N levels: high (N2) and low (N1). Eight yield-related traits, including grain yield, oil content and oil yield were evaluated. Reactivity to a change of N regime was calculated as: N2-N1, N1/N2, ΔN/N2. The environment stress intensity was evaluated by Nitrogen Nutrition Index (NNI). QTLs were detected by Composite Interval Mapping and Multiple Interval Mapping methods using a 2301 SNP and 351 SNP genetic maps for the AM and DK populations respectively. Md-location was more stressed than LR, with lower NNI values and more intense water stress. A mixed model analysis on all location x year combinations revealed significant genotypic and nitrogen effects on most traits for AM and DK. However, genotype x N effect was detected in Md location only. Heritabilities were overall higher in N2 than in N1. 137 QTLs were detected: 55 N1-QTLs, 47 N2-QTLs and 35 reactivity-QTLs. Eight hotspots of QTLs involved in oil yield establishment were revealed: a particular dense zone was found on the A05 linkage group with 24 QTLs. The few number of common QTLs between crop sites and/or N treatments and the detection of reactivity-QTLs highlighted a strong QTL x environment interaction (QEI). Moreover reactivity-QTL did not co-localize with N1 or N2-QTL. A precise dissection of QEI would be the next step for a deeper understanding of oil yield elaboration under N constraints.

Effect of defoliation on seed yield and nitrogen uptake of oilseed rape cultivars differing in nitrogen efficiency

Abdullah Ulas[1,2], Torsten Behrens[1], Franz Wiesler[1,3], Walter J. Horst[1],
Gunda Schulte auf'm Erley[1,4]

[1]Institute for Plant Nutrition, Leibniz University of Hannover, Germany; [2]present address: Soil Science and Plant Nutrition Department, University of Erciyes, Turkey; [3]present address: LUFA Speyer, Germany; [4]present address: Institute of Plant Nutrition and Soil Science, Christian Albrechts University Kiel, Germany, schulteaufmerley@plantnutrition.uni-kiel.de

Oilseed rape is one of the crops with the highest N balance surpluses in European agriculture. A reduction of the N surpluses could be achieved by a cultivation of N-efficient genotypes, which are capable of achieving a high yield under N-limiting conditions. Previous studies have shown that N-efficient rape cultivars are characterized by a prolonged photosynthetic activity through delayed leaf senescence (stay-green) during reproductive growth at limiting N (Schulte auf'm Erley et al. 2007) and by maintaining a high N uptake activity during reproductive growth (Schulte auf'm Erley et al., 2011). From these results we concluded that continuous assimilate supply from the leaves is necessary for the high N uptake during reproductive growth of N-efficient cultivars. The aim of this study was to investigate the role of leaves for yield and N uptake of oilseed rape cultivars differing in N efficiency. It was hypothesized that defoliation causes a shortage of assimilates to the roots and thus decreases N uptake during reproductive growth, especially for the N-efficient cultivar.

Two winter oilseed-rape cultivars differing in N efficiency were grown at three N rates in a three-year field experiment performed near Göttingen, Germany. Defoliation was carried out at the beginning of flowering by cutting every second leaf from the base of the plants. Harvests were performed at beginning of flowering and at early maturity. Dry weights and N contents were determined for all plant fractions.

Seed yield, shoot dry matter, and shoot N uptake at maturity were significantly reduced by defoliation as compared to control plants for both cultivars and at all N rates. In contrast, defoliation did not decrease shoot growth and N uptake after beginning of flowering. The lower shoot dry matter and N uptake due to defoliation was thus due to the removal of the cut leaves, and not to a further negative impact of the defoliation treatment on growth or N uptake of the plants. Both cultivars significantly reduced their seed yield and shoot N uptake at low N supply, while at medium and high N, the reduction in seed yield and shoot N at maturity was somewhat stronger for the N-efficient cultivar.

The overall negative impact of defoliation on seed yield demonstrated that leaves are important for yield formation in oilseed rape. The hypothesis, that assimilate supply from the leaves enhances N uptake during reproductive growth at strongly limiting N conditions could not be confirmed by this experiment. Instead, the importance of the leaves for yield may be due to assimilate remobilization from the leaves during reproductive growth.

References

Schulte auf'm Erley, G., Wijaya, K.-A., Ulas, A., Becker, H., Wiesler, F. and Horst, W.J. (2007) Leaf senescence and N uptake parameters as selection traits for nitrogen efficiency of oilseed rape cultivars. Physiol. Plant. 130, 519–531.

Schulte auf'm Erley, G., Behrens, T., Ulas, A., Wiesler, F. and Horst, W.J. (2011) Agronomic traits contributing to nitrogen efficiency of winter oilseed rape cultivars. Field Crops Res. 124: 114-123.

Nitrogen use efficiency of a *Brassica napus* population segregating into normal and semi-dwarf types

Sebastian Miersch, Heiko C. Becker

Georg-August-Universität Göttingen, Department of Crop Sciences, Von-Siebold Strasse 8, 37075 Göttingen, Germany; smiersc@gwdg.de

Winter oilseed rape (*Brassica napus* L.) is the most important oil crop in the EU-27. The cultivation of oilseed rape (OSR) is characterized by a high nitrogen fertilizer input and large amounts of nitrogen (N) which can remain in the soil after harvest (Rathke et al. 2006). Therefore N leaching is often an important problem after growing winter OSR. Due to ecological as well as economical aspects breeding for improved nitrogen use efficiency (NUE) is becoming more and more important to plant breeders. NUE of a genotype is defined as the ability to produce a high yield in a soil that is N limiting for a standard genotype. One approach to increase NUE is to improve the harvest index (HI) of OSR by using dwarf genes to reduce vegetative biomass and maintain or increase seed yield.

From a cross between a normal growing resynthesized line and a dwarf form of a common OSR cultivar a DH population was developed. The dwarf form of the cultivar was generated by backcrossing with a dwarf mutant (Foisset et al. 1995) The resulting DH lines segregate into dwarf and normal growing lines. All DH lines were crossed to a normal growing, male sterile tester to produce test cross hybrids (TC). The TC segregate into semi-dwarf and normal growing genotypes.

In 2010/11 150 TC (75 normal, 75 semi-dwarf genotypes) were grown in replicated field trials at two locations (Göttingen and Einbeck) without N fertilization (N0). In 20011/12 and 2012/13 108 TC (54 normal, 54 semi-dwarf genotypes) were grown in replicated trails at these two locations with two N levels (no fertilization (N0) and optimal N fertilization (N1)). Plot sizes were11.25 m^2 or 18 m^2. For the phenotypic assessment we collected data for flowering time, plant height, seed yield, straw yield as well as N-content in seeds and straw. All DH-lines were genotyped with SSR and SNP markers to construct a genetic linkage map and perform a QTL analysis.

At both N levels the semi-dwarf types produced significantly higher seed yields compared to the normal type lines. The combination of higher grain yield together with less straw yield, resulted in an improved harvest index (HI). The QTL analysis with major QTL for grain yield, straw yield and HI at the position of the dwarf gene (*Bzh*) confirmed these results.

In conclusion it seems that semi-dwarf OSR types are more N efficient than normal growing types.

The authors gratefully acknowledge funding from the European Community for the Integrated Project NUE-CROPS. We thank Frank Breuer and Andreas Gertz, KWS Saat AG, for providing plant material, performing field trials and marker analyses.

References

Foisset N, Delourme R, Barret P, Renard M. 1995. Molecular tagging of the dwarf BREIZH (Bzh) gene in Brassica napus. Theor. Appl. Genet. 91: 756–761

Rathke G-W, Behrens T, Diepenbrock W (2006) Integrated nitrogen management strategies to improve seed yield, oil content and nitrogen efficiency of winter oilseed rape(*Brassica napus* L.): a review. Agric Ecosyst Environ 117:80–108

Detection of quantitative trait loci for grain yield and correlated traits under high and low soil nitrogen conditions in a novel mutant x progenitor maize DH population

Stefan Tsonev[1], Viliana Vasileva[2], Elena Todorovska[1], Thomas Presterl[3], Nikolai K. Christov[1]

[1]Agrobioinstitute, 8 Dragan Tsankov blvd., 1164 Sofia Bulgaria, [2]Institute of forage crops, 89 Gen. Vladimir Vazov st., 5800 Pleven, Bulgaria; [3]KWS SAAT AG, 37555 Einbeck, Germany, nikolai_christov@abi.bg

Introduction

Tolerance to low nitrogen conditions is a highly desired characteristic for sustainable maize production. Despite of numerous studies exploring natural variations to detect quantitative trait loci (QTLs) for low N tolerance in maize, many of them used parents that had no breeding value to maximize the phenotype variation, thus limiting the utility of the detected QTLs in the MAS breeding programs. The QTL approach applied in the present study, explores the genetic variation generated by chemical mutagenesis in an elite temperate breeding line. For this purpose a DH population was generated from a cross between an elite progenitor line B37 and a mutant line. The mutant inbred was developed by chemical mutagenesis treatment of B37 dry seeds to induce variation, followed by recurrent reciprocal breeding to evaluate and fix the desirable mutations in homozygous state.

Material and methods

A subset of 192 DH lines derived from the cross between a mutant inbred line XM 87 136 and and its progenitor line B37 was used. For the agronomic evaluation, each DH line was crossed to an unrelated tester (Mo17), in order to study tolerance to low soil N availability at the hybrid level. The tester was chosen for its high combining ability for grain yield with both parental lines of the DH population. The test-cross hybrids were evaluated in field trials at one location with 2 N levels (0 and 200 kg /ha) and 2 irrigation regimes (rain fed and irrigated) in 2010 and 2011.

Results and discussion

Detection of QTLs for grain yield (GY) and correlated traits, including grain moisture content (GMC), plant height (PH), and ear height (EH), was performed by composite interval mapping with the phenotype data from two rainfed low N (2010, 2011) and one irrigated high N (2010) trials. A major QTL for GY on chromosome 5 was detected in both high N trial and a series of rainfed low N trials, averaged across two years. The QTL location overlapped with QTLs for PH and EH detected in all analyzed trials and moisture QTL detected in low N trials only. Two additional grain yield QTLs on chromosomes 8 and 10 were detected in high N conditions.

These results demonstrate the usefulness of a mutant x progenitor population for understanding of the genetic basis of complex traits, such as NUE, and will be useful for developing marker-assisted selection in maize breeding programs.

Acknowledgement

The authors gratefully acknowledge funding from the European Community financial participation under the Seventh Framework Programme for Research, Technological Development and Demonstration Activities, for the Integrated Project NUE-CROPS FP7-CP-IP 222645.

The views expressed in this publication are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission.

Optimising nutrient use efficiency in wheat and potatoes: interactions between genotypes and agronomic practices

Eleanor Swain[1], Caroline H. Orr[1], Leonidas Rempelos[1], Gavin Hall[1], Rachel Chapman[1], Mftah Almadni[1], Elizabeth A. Stockdale[2], Carlo Leifert[1], Julia M. Cooper[1]

[1]*Nafferton Ecological Farming Group (NEFG), Newcastle University, Nafferton Farm, Stocksfield, NE43 7XD, UK;Julia.Cooper@newcastle.ac.uk*
[2]*Crops, Soils and Environment Group, School of Agriculture Food and Rural Development, Newcastle University, Newcastle, UK, NR1 7RU*

Introduction

The NUE-CROPS project focuses on the identification of molecular markers for improved nutrient use efficiency (NUE) in four major European crops (maize, oilseed rape, wheat, potato) in order to maintain long term farm fertility and yields whilst minimising the environmental impact. However, it is recognized that a combination of agronomic best practice and NUE varieties represent the best strategy for improving system scale NUE.

Materials and methods

At NEFG, varieties of wheat and potatoes with varying NUE were grown in a long-term farming systemstrial that compares organic and conventional crop rotations, fertility management (compost vs. NPK), and crop protection practices (organic vs. conventional). A nutrient budgeting approach was used, in combination with N modelling, to assess the NUE of the different systems.Nutrient budgets were calculated for the full crop rotation, using data for nutrient inputs from compost or NPK fertiliser, and nutrient removal by crop harvest. N losses by leaching/denitrification were modelled using NDICEA (van der Burgt, et al., 2006).

Results and discussion

Preliminary results indicate that crop rotation does not have a significant effect on crop yields, howeverthe use of grass/clover leys in the rotation can make a significant contribution to the N supply for crops in the year after ploughing without the need of additional fertiliser. NPK fertiliser inputs significantly increasedthe yielding capacity of the crops. Crops treated with conventional crop protection amendments had significantly increased yields compared to those treated with organic crop protection, primarily due to the increased weed and pest presence under organic protection.Potato varieties exhibited differences in NUE, which were primarily correlated with differences in yield. These effects were particularly significant where amid-season potato (Sante) was compared with a significantly higher yielding late-season variety (Sarpo Mira).There were no significant yield differences observed in the Winter wheat(Cordiale and Scaro) and Spring wheat varieties (Paragon and Tybalt).The use of NPK fertiliser resulted in higher levels of residual N, and greater risk of N leaching after crop harvest in the conventional rotation, in spite of deficits in calculated N budgets. TheN budgets for the organic crop rotation regardless of N source resulted in an N surplus, reflecting higher N inputs by biological fixation. In the case of P, efficiency of crop uptake in a single year is not as important, since unused P remains in the soil and is available for subsequent crops. However, for N, inefficient use in a single year has a significant effect on the N efficiency of the cropping system.

van der Burgt, G. J. H. M., Oomen, G. J. M., Habets, A. S. J., & Rossing, W. A. H. (2006). The NDICEA model, a tool to improve nitrogen use efficiency in cropping systems. *Nutrient Cycling in Agroecosystems, 74*, 275-294.

Genetic diversity for mycorrhiza infestation and its importance for adaptation of sorghum to phosphorus limited soils in West Africa

Willmar L. Leiser[1,2], *H. Frederick W. Rattunde*[2], *Marcus Olalere Olatoye*[1], *Eva Weltzien*[2], *Bettina I.G. Haussmann*[1]

[1] *Institute of Plant Breeding, Seed Science and Population Genetics, University of Hohenheim, 70593 Stuttgart, Germany,* [2] *International Crops Research Institute for the Semi-Arid Tropics, BP 320 Bamako, Mali; willmar_leiser@uni-hohenheim.de*

Sorghum (*Sorghum bicolor* L. *Moench*) is a staple crop of the Savannah Zone of West- and Central Africa (WCA). Limited soil-phosphorus (P) availability is a serious and frequent constraint to sorghum growth and productivity across the range of rainfall zones in West Africa. Genotype selection under low P conditions is necessary and effective in identifying sorghum genotypes which are specifically adapted to low P soils (Leiser et al., 2012). However, there is limited knowledge on the specific adaptation mechanisms of these genotypes. Mycorrhiza infestation of plant roots is known to be a major factor contributing to P uptake (Bagayoko et al., 2001). The objective of the present study was to investigate the role of mycorrhiza-symbiosis in the adaptation of WCA sorghums to low-P soils. 188 diverse sorghum genotypes were grown for 38 days in a low P soil in 10L pots and fine root samples were analyzed for their mycorrhiza infestation rate. There was significant genotypic variation for mycorrhizal colonized root length and vesicle score, but a low repeatability for both traits (0.19 and 0.27, respectively) within the trial. Mycorrhiza was negatively correlated to shoot biomass, P concentration and P uptake. Selected genotypes specifically adapted to low P soils, showed significantly higher mycorrhiza infestation rates than genotypes adapted to high P soils. However no clear relationship between grain yield on low P fields and mycorrhiza infestation rate at an early plant developmental stage could be found across all genotypes. Selecting genotypes for mycorrhiza infestation at an early stage in plant growth does not seem promising to identify genotypes with higher grain yields under low P soil conditions. Further research at a later plant growth stage is necessary and is currently performed, but at the time of writing this abstract the data have not been available.

References

Bagayoko, M., E. George, V. Römheld, and A. Buerkert. 2001. Effects of mycorrhizae and phosphorus on growth and nutrient uptake of millet, cowpea and sorghum on a West African soil. The Journal of Agricultural Science. 135: 399–407.

Leiser, W.L., H.F.W. Rattunde, H.-P. Piepho, E. Weltzien, A. Diallo, A.E. Melchinger, H.K. Parzies, and B.I.G. Haussmann. 2012. Selection Strategy for Sorghum Targeting Phosphorus-limited Environments in West Africa: Analysis of Multi-environment Experiments. Crop Sci. 52: 2517–2527.

Improving phosphorus use and uptake efficiency of sorghum

Sebastian Parra-Londono, *Ralf Uptmoor*

Faculty of Agricultural and Environmental Sciences, University of Rostock, Justus-von-Liebig-weg 6, 18059 Rostock, Germany; sebastian.parra-londono@uni-rostock.de

Sorghum is grown worldwide as staple food, fodder and for biofuel production. Crop productivity is often limited by low nutrients availability, resulting in reduced plant yields. Phosphorus (P) availability is declining in many soils and intensive P fertilization is uncommon in developing countries and might be detrimental as a long-term strategy. Since phosphate reacts with chemical and soil particles, P is highly immobile in the soil. Therefore, a plant-based strategy to improve P efficiency is considered as a reliable approach. Morphological and physiological root characteristics are important traits, which determine the uptake efficiency of nutrients with low mobility in the soil. Root strategies based on soil-exploration and phosphate mobilization from poorly available P pools in the rhizosphere as shallow root growth angle, improved lateral branching and high root hair density enhance topsoil foraging and improve P acquisition.

Quantitative genetic mechanisms controlling nutrient efficiency are still incompletely understood. Further efforts on deep phenotyping assessments are needed. Due to the importance of root architecture for nutrient uptake and the complexity of its evaluation in soil and field trails, new approaches for root phenotyping have been suggested. Novel and original methodologies based on two- and three-dimensional image analyses are used to obtain descriptions of the rooting system at low cost and high throughput.

The present research has the aim of detecting quantitative traits loci (QTL) associated to root architectural parameters in sorghum, using a sorghum diversity set and a two-dimensional root phenotyping method. A critical step in our study is the standardization of a plant growing system for a rapid and reliable root assessment. Since the evaluation of root traits is based on image-analysis, plants are grown in transparent "rhizoboxes" fitting a nylon mesh to avoid rooting into the soil behind the net. Root system images are analyzed using the free available software SmartRoot. In a preliminary experiment, sorghum plants were fertilized with two P-sources (KH_2PO_4 and $Ca_3(PO_4)_2$). Differences among genotypes were observed especially in lateral rooting. Additional experiments are being carried out to phenotype the complete diversity set for carrying out genome wide association studies.

Root architectural parameters are controlled by many genes and the identification of the regions within the sorghum genome that contain such genes will enhance the knowledge about the genetics of P efficiency in sorghum and could lead to the identification of candidate genes and to develop markers for marker-assisted selection.

Phosphorus efficiency of potato varieties

Siri Caspersen[1], *Joakim Ekelöf*[1] *and Ulrika Carlson-Nilsson*[2]

[1]*Department of Biosystems and Technology,* [2]*Department of Plant Breeding and Biotechnology, Swedish University of Agricultural Sciences, SE-230 53 Alnarp; Siri.Caspersen@slu.se*

Introduction

The potato plant is reported to have a relatively low phosphorus efficiency. As a consequence, phosphorus recommendations are often high compared to other agricultural crops. However, phosphorus is a non-renewable resource that contribute to eutrofication and algal blooms of freshwater, seas and coastal systems. Thus, there is a need to improve the use efficiency of phosphorus in crop production systems. For several agricultural and horticultural crops, genotype differences in phosphorus efficiency have been shown to occur. A variety with a higher phosphorus efficiency may have a lower phosphorus need for optimal growth, or the root system may have a higher ability to acquire phosphorus. Roots have different adaptations for increasing the availability of phosphate; e.g. an extensive and finely branched root system or a high density of root hairs. An efficient variety may also have a higher ability to exude protons to reduce pH or to release phosphatases or organic acids to increase the availability of phosphate ions to the plant root. Most agricultural and horticultural plant species do also form symbiosis with arbuscular mycorrhizal fungi which may take up phosphorus by the finely branched network of external hyphae and transport phosphorus to the host. By determining differences in phosphorus requirement for commonly used potato varieties, fertilizer levels could be better adapted to the need and uptake capacity of the crop. Also, by determining the factors contributing to an efficient phosphorus utilization for the potato plant, more efficient varieties could be selected.

Materials & Methods

During 2011 and 2012, field experiments have been conducted in Southern Sweden to compare phosphorus utilization for six different potato varieties including early, intermediate and late maturing types. Soils containing low levels of available phosphorus have been selected for the experiments and phosphorus fertilizer have been added in the amounts of 0, 30 and 60 kg P per ha.

Results and Discussion

In 2011, soil heterogeneity was large and tuber yields responded significantly to phosphorus fertilization only as a mean of the six varieties tested. In 2012, an increase in tuber yield with the addition of phosphorus was significant for most varieties. Phosphorus fertilization improved yields mainly by increasing the weight of the larger tuber fractions. The phosphorus use efficiency, calculated as tuber dry weight per added amount of phosphorus, was generally higher for the late varieties. The study confirms that there are differences in phosphorus use efficiency between potato varieties and indicates that late varieties might be more suitable than early and intermediate varieties for locations were the risk of nutrient losses is high.

CO_2-utilization efficiency of winter barley genotypes

Esther Mitterbauer[1], Jürgen Bender[1], Antje Habekuß[2], Matthias Ender[2], Martin Erbs[1], Frank Ordon[2], Hans-Joachim Weigel[1]

[1]Thünen-Institute of Biodiversity, Bundesallee 50, 38116 Braunschweig, Germany, esther.mitterbauer@ti.bund.de, [2]Julius Kühn-Institute of Resistance Research and Stress Tolerance, Erwin-Baur-Str. 27, 06484 Quedlinburg, Germany

Introduction

Carbon dioxide (CO_2) is the most important substrate for plant biomass production but little information is available about the efficiency of how and to which extent plants can utilize the predicted further increase in atmospheric CO_2 concentration. Principally, higher CO_2 concentrations lead to higher photosynthetic rates and higher biomass production (CO_2 fertilization effect). Considerable variations in plant species and cultivars are known but hardly any experiments were performed to investigate genotypic variation of broader gene pools systematically in the field so far. This would be a first step to make the CO_2 -use efficiency exploitable for plant breeding.

Materials and Methods

In open-top chamber experiments we investigated the reactions of 100 winter barley genotypes to elevated CO_2 (e[CO_2]) under field conditions. The genotypes that were prior analysed with the Illumina 9k iSelect chip were grown at two different CO_2 levels: ambient air (~390 ppm CO_2) and elevated CO_2 ((e[CO_2]); ~700 ppm CO_2) throughout the whole growing season 2012. The genotypes were phenotyped and the phenotypic data were used in genome wide association analyses. ESTs from literature were aligned with the barley data base entries *in silico*. Candidate genes were selected for subsequent genetic association studies.

Results and Discussion

Yield and above ground biomass (dry weight) increased approximately to the same extent by 37 and 32%, respectively, under e[CO_2] in the season 2011/12. They were mainly affected by the number of seeds per ear (+15%) and the number of ears per plant (+16%), and by the weight of ears (+40%) and straw (+47%). The genotypes differed significantly for the investigated traits and revealed a broad genetic variability in winter barley concerning its reaction to e[CO_2]. Furthermore, elemental analyses revealed differences in the grain carbon and nitrogen contents between genotypes and treatments.

Different conversion abilities of CO_2 to glucose or different stomatal conductances might be responsible for the different extent of the use of the additionally provided CO_2. Therefore, we investigated a subset of the genotypes by mass spectrometry and their leaf structure. The genotypes differed in their carbon isotope discrimination which ranged from -26.7 to -29.8 ‰ and their number of stomata per square centimetre (51 - 79 stomata * cm^{-2}).

First marker-trait association analyses for yield and biomass identified four markers located on different linkage groups. Sequence alignments of already published e[CO_2]-sensitive ESTs from various species resulted in significant hits to sequences in the barley data base. Genome wide and genetic association analyses might lead to functional markers for the selection of genotypes with a high CO_2-utilization efficiency to meet future plant production demands.

Development of a screening technique for selecting drought tolerant in cocoa

Atta Ofori

Cocoa Research Institute of Ghana, P O Box 8, Akim Tafo, ofori77@yahoo.com

Drought stress is one of the most important environmental factors limiting cocoa cultivation in most parts of Africa especially in Ghana. Forest areas where cocoa were formerly grown are currently unavailable leading to its cultivation in denuded areas with stress conditions. Developing a screening technique for selecting drought tolerance cocoa genotypes for cultivation in denuded areas is urgently needed in cocoa production. Ten cocoa genotypes, with two reported as drought tolerance in previous studies and an open pollinated group as control were used in the evaluation. 12 seedlings per genotype arranged in RCD were subjected to three sequential cycles, consisting of progressive (three weeks without watering) and moderate (watering once a week for three weeks). The control plants were watered every other day throughout the experiment. The following parameters were measured during the moderately drought periods: physiological (stomatal conductance, photosynthetic rate, transmission rate, leaf relative water content and chlorophyll content) and morphological (wilting scores, stem diameter growth and survival scores). Genotypes were separated into drought tolerance and susceptible at either the second or third cycle of progressive drought when rug plots were used to study the effect of drought across cycles. The most sensitive physiological parameters that discriminated among the genotypes were photosynthetic rate, transmission rate and chlorophyll content, and correlated strongly ($p<0.001$) with survival and wilting scores. PCA using correlation matrix grouped the genotypes into control, tolerance and susceptible. The results suggest that some of the parameters could be used to select drought tolerance cocoa genotypes and their implications will be discussed.

Quantification of root distribution in faba bean-oat intercrops by Fourier Transform Infrared (FTIR) Attenuated Total Reflection (ATR) spectroscopy

Catharina Meinen, Rolf Rauber

Georg-August-University Goettingen, Department of Crop Sciences, Von-Siebold-Str. 8, 37075 Goettingen, Germany; catharina.meinen@agr.uni-goettingen.de

Introduction

Intercropping of grain legumes with cereals often overyield sole crops. The intercrop partners benefit from each other due to reduced intraspecific competition and use resources more efficiently (e.g. exploit different soil depth). To study species specific rooting patterns, roots have to be identified to species level. In this study, we used Fourier Transform Infrared (FTIR) Attenuated Total Reflection (ATR) spectroscopy to discriminate roots of faba bean and oat. Furthermore, we quantified root mixtures of faba bean and oat from intercrops according to species.

Material and methods

A replicated field experiment with faba bean (*Vicia faba* L., cultivar Fuego) and oat (*Avena sativa* L., cultivar Contender) in sole and intercropped plots was carried out in 2012. The sole crops were drilled with 40 seeds of faba bean m^{-2} and 300 seeds of oat m^{-2}. The additive intercrops consist of 100 % faba bean and 50 % oat in alternate rows. Roots from the sole plots were used to prepare artificial samples of faba bean and oat root mixtures (5 % steps) to calibrate and validate a FTIR-ATR model. Species proportion of faba bean and oat root mixtures of the intercropped plots (0-60 cm soil depth) was predicted by the model.

Results and discussion

The cross validated model showed a high coefficient of determination (93.8) and a root mean square error of cross validation (RMSECV) of 8.13. The external validation revealed also a high coefficient of correlation of 0.95 and a root mean square error of prediction of 8.9. This model was used to predict species proportions in the intercrop root samples.

In 0-10 cm soil depth, oat accumulated on a row similar root dry masses in sole crops (135.7 g m^{-2}) and in intercrops (124.1 g m^{-2}). With increasing soil depth, oat root dry mass decreased strongly, especially in the intercrops. In 0-10 cm soil depth, faba bean produced 90.7 g m^{-2} dry root mass in the sole crops and 52.6 g m^{-2} in the intercrops. In sole crops, faba bean root mass decreased with increasing soil depth whereas in the intercrops, root dry mass in 10-20 cm (31.2 g m^{-2}) and 20-30 cm (30.6 g m^{-2}) were quite similar.

In the intercrops, 13 % of oat roots are placed under the faba bean rows whereas only 8 % of faba bean roots are positioned under the oat rows.

The results indicate that faba bean and oat shift their roots to different soil depth in intercrops compared to sole crops. Both root systems overlap in the intercrops. However, oat roots explore more strongly the soil under faba bean rows than faba bean roots under oat rows.

Root development of wheat is influenced by barley chromosome 4H in wheat/barley addition and substitution lines

Nikolett Réka Aranyi[1]*, Márta Molnár-Láng*[2]*, Borbála Hoffmann*[1]

[1]*Georgikon Faculty, University of Pannonia, H-8360, Keszthely, Festetics u. 7. Hungary; hoff-b@georgikon.hu,* [2]*Agricultural Institute, Centre for Agricultural Research, Hungarian Academy of Sciences H-2462, Martonvásár, POB 19, Hungary*

Introduction

Increasing drought tolerance in cereals is one of the most important challenges for food production. Because deep rooting is beneficial to acquire moisture from deeper soil layers, it is important to examine root characteristics of the breeding material. Hybridization between related species makes it possible to transfer useful traits from one species into another. The introgression of barley (*Hordeum vulgare* L.) chromosomes into wheat (*Triticum aestivum* L.) may result among others in the transfer of drought-tolerance from barley into wheat.

Material and methods

The selection of genotypes for this study was based on previous results from pot and field experiments Aranyi et al. (2012). 4H addition line originating from winter wheat 'Martonvásári9kr1'/winter barley 'Igri' and 4H(4D) substitution line from 'Martonvásári9kr1' /spring barley 'Betzes' (Molnár-Láng et al., 2000) were investigated to determine how the added barley chromosome influences rooting ability and drought tolerance of wheat. The genotypes were grown in a sand-tube experiment according to Ehdaie et al. (2012) in an unheated glasshouse in a randomized complete block design with four replicates. Plants were grown in polyethylene tubing bags sleeved into PVC tubes 75 cm long and 10 cm in diameter. Bags were filled with dry silica sand #30. Tubes were irrigated with half-strength Hoagland solution. In the well-watered treatment tubes were irrigated as needed. Drought was initiated at booting stage by providing 50% of irrigation solution given to the well-watered tubes. Plants were harvested at maturity. After plant height, number of tillers and spikes were recorded, shoots were excised at the root/shoot interface. Grain yield, number of grains and grain weight were measured. To retrieve intact root systems, each polyethylene bag was pulled from the PVC tube and was laid on a screen frame in a tub and cut length wise. Intact root system was floated to the water surface and washed carefully. Shallow and deep root weight and total root biomass were determined, ratio of shoot/root dry weight was calculated.

Acknowledgement:

This project was realized with the support of the project TÁMOP 4.2.4.A/2-11-1-2012- 0001 of the Hungarian Government with the co-funding of the European Social Fund.

Referens

Aranyi, N., Molnár-Láng, M., Hoffmann, B. (2012). Búza-árpa introgressziós vonalak agronómiai tulajdonságainak vizsgálata. (Examination of agronomic traits of wheat-barley introgression lines). *Növénytermelés (Crop Poduction)* 61(2): 5-19.

Bahman, E., Layne, A., Waines, J. (2012). Root system plasticity to drought influences grain yield in bread wheat. *Euphytica,* 186(2): 219

Molnár-Láng, M., Linc, G., Logojan, A., Sutka, J. (2000). Production and meiotic pairing behaviour of new hybrids of winter wheat (Triticum aestivum) x winter barley (Hordeum vulgare). *Genome,* 43: 1045-1054.

Root growth responses of barley to planting density.

Vera L. Hecht, Johannes A. Postma, Vicky M. Temperton

Institut für Bio- und Geowissenschaften (IBG-2), Forschungszentrum Jülich (Jülich Research Center), Wilhelm-Johnen-Straße, 52428 Jülich, Deutschland, v.hecht@fz-juelich.de

We systematically compare plant growth of single plants and populations or clusters with focus on the effect of planting density on root growth and architecture.

We conduct planting density experiments both in the lab and in the field using two different barley lines, namely an introgression line (IL) which is a cross of a German cultivar, Scarlett (Sca), and an Israelic wild accession, and its German parent Scarlett (Sca).The genotypes of the two lines are very similar, but they exhibit a very contrasting root system as previously shown by Naz *et al.* (2012), found for single plants of these lines: Root dry mass, root volume and maximum rooting depth are significantly higher in IL – and here, it is more similar to its Israelic parent – than in the German parent. In a greenhouse experiment, we grew these two lines in rhizotrons at a low planting density (single plant) and a high planting density (5 plants per rhizotron) over a period of 3 weeks to study root growth and architecture non-invasively. The outcome confirmed the differences between the two lines found by Naz *et al.* (2012). Additionally, the first results indicate a different response of the two barley lines to planting density.

To further investigate the response (especially of roots) to planting density, we will perform more experiments in the lab (namely, non-invasively in rhizotrons as well as in MRI for assessing root dynamics)) and in the field. Here, we will compare growth performance of isolated plants to a range of planting densities. We expect, especially for Sca, certain traits like maximum rooting depth or root dry weight to change the earlier the higher the planting density indicating an earlier respond to neighbors in higher planting density. Furthermore, overall root architecture focusing on proportions of whole root systems found in different rooting zones (at specific depth) will be used as a method to measure root architecture at different depth. This kind of research will give us insight into the plasticity of plant performance and the influence of neighbors and will allow us a better comparison of lab and field results.

Early root growth phenotyping and drought tolerance evaluation in tomato genotypes from different breeding environments

V. Allerstorfer[1], H. Weissinger[1], J. Balas[1], B. Horneburg[2], G. Bodner[1], H.-P. Kaul[1]

[1]*Department of Crop Sciences, University of Natural Resources and Life Sciences, Vienna; helene.weissinger@boku.ac.at*
[2]*Department of Crop Sciences, University of Göttingen*

The aim of this study was the evaluation of the reaction of several tomato genotypes from different breeding environments to drought stress. In total, we screened thirteen genotypes of different origins categorized in old and new ones, conventionally and organically bred ones, and genotypes bred in different continents, as well as parental lines and progenies. These genotypes were a subset of genotypes tested within the framework of the Organic Outdoor Tomato Project (Horneburg & Becker, 2011) in field experiments at the University of Göttingen.

A pot experiment with two levels of water supply was conducted. After growing the plants in pots for five weeks, chlorophyll fluorescence and chlorophyll content of leaves were measured and current water content and osmotic potential of single leaves were assessed. After eight weeks in the pots, fresh weight, dry weight, and current water content of shoots and roots were determined. Data was analyzed statistically by t-tests to compare non-stressed and stressed plants in the mean of all genotypes and for each single genotype.

As first results, stressed plants showed significantly lower fresh weight of roots and shoots, current water content of roots, and significantly higher osmotic potential, root:shoot ratio and chlorophyll content in the mean of all genotypes.

Under drought stress, the new organically bred cultivars 'Primavera' and 'Clou', the old conventionally bred cultivars 'Hildares F1' and 'Matina', and the "wild" tomato 'Golden Currant' produced most shoot dry matter, whereas without stress, 'Primavera' and 'Resi' (a cultivar received from a private seed saver) produced most shoot dry matter. 'Hildares F1' also showed above-average growth when not stressed, whereas 'Clou' showed average growth. 'Matina was the only cultivar without significant reduction of shoot dry matter when stressed; shoot dry matter of non-stressed plants was the lowest of all cultivars and in the mean of both water supply levels, also root dry matter was lowest of all cultivars. ´Primavera´ was the only cultivar showing no reduction of root dry matter when stressed. Interestingly, in the mean of both treatments, root:shoot ratio was lowest in 'Matina', 'Clou' and 'Primavera' (0.38; 0.40; 0.42) and highest in 'LBR11', a cultivar from Thailand (1.08). The experiment revealed significant genotypic differences in the reaction to drought stress that may be used in breeding programs for environments limited in water supply.

References

Horneburg, B. & Becker, H. C. (2011) Selection for *Phytophthora* field resistance in the F2 generation of organic outdoor tomatoes. Euphytica 180: 357-367.

Wheat breeding and AMF colonisation: a multi-farm trial

Serpolay Estelle[1], Sbrana Cristiana[2], Avio Luciano[2], Giovanetti Manuela[3], Chable Véronique[1]

[1]INRA SAD, Cultivated biodiversity and participatory research, Domaine de la Motte, BP 35327, 35653 Le Rheu, France,;[2]IBBA-CNR, UOS Pisa, Via del Borghetto 80, 56124 Pisa, Italy, [3]Department of Agriculture, Food and Environment, University of Pisa, Via del Borghetto 80, Pisa, Italy, veronique.chable@rennes.inra.fr

Introduction

Symbiosis between plants and Arbuscular Mycorrhizal Fungi (AMF) is more important in organic farming than in conventional one (Ryan *et al.*, 1994), increasing the uptake of key plant nutrients, such as N and P (Blanke et al., 2011). However, the symbiosis efficiency depends on environmental factors and, for wheat, also on genotype, "old" varieties being more susceptible to AMF colonisation (Hetrick *et al.*, 1992).

In the framework of the SOLIBAM European project, we performed an explorative work across an on-farm trials network in order to verify whether Genotype x Environment (G x E) interactions can be detected, according to the intra-varietal diversity.

Material and Methods

Methodological approach was initiated with 3 wheat varieties representing different genetic structures (pure line, single population and mixture of populations). They were cultivated in different organic farms in 2011 (1 farm), 2012 (3 farms) and 2013 (5 farms). Agronomic and environmental traits were collected, as well as AMF colonization data and grain composition.

To investigate the G x E interactions, we will correlate the rate of AMF colonization to grain composition (proteins and starch) and other crops performance for the three varieties on the different farms, in order to evaluate emerging trends and the efficiency of this methodological approach.

Results

Preliminary results show trends confirming that the modern variety is less colonized by AMF than populations. Further results will enrich this vision and enable us to reveal the relationship between AMF, quality and crop performance according to environments.

With results from other farms and their associated environmental data, we expect to better explore G x E interactions on colonization efficiency.

Discussion

The breeding criteria for organic farming and local adaptation in different farms and wheat varieties will be discussed in order to verify the reliability of our preliminary methodological approach.

Blanke, V., Wagner, M., Renker, C., Lippert, H., Michulitz, M., Kuhn, A., Buscot, F., 2011. Arbuscular mycorrhizas in phosphate-polluted soil: interrelations between root colonization and nitrogen. *Plant and Soil* 343, 379-392.

Ryan, M. H., Chilvers, G. A. & Dumaresq, D. C. (1994). Colonisation of wheat by VA-mycorrhizal fungi was found to be higher on a farm managed in an organic manner than on a conventional neighbor. *Plant and soil*, 160: 33-40.

Effect of Nitrogen Inhibitor (DMPP) on Seed Yield and Quality in Winter Wheat

Muhammet Kemal Gül[1], *Sami Süzer*[2]

[1]*EuroChem Agro Turkey Tarım San ve Tic. Ltd. Şti. Büyükdere Caddesi No: 7;*
GIZ 2000 Plaza 34398 Maslak/ Istanbul-TURKEY, muhammet-kemal.gul@eurochemagro.com
[2] *Trakya Agricultural Research Institute, D-100 Karayolu Üzeri Çevik Kuvvet Şube Müdürlüğü Yanı Merkez 22000 Edirne-TURKEY*

High wheat yield and seed quality is very important for human and animal nutrition. As quantitative traits, wheat yield and quality are affected by environmental and cultural factors like fertilization, plant protection etc. The application of nitrogen is one of the most important cultural factors. Due to leaching and volatization problems of nitrogen, it is not easy to provide permanent nitrogen availability in the soil during the generative development of wheat. To prolongate this availability of nitrogen as ammonia and nitrate is a main objective to develop fertilizer with long term effect for plant production.

Nitrification inhibitors are chemical compounds that slowdown the nitrification process. 3,4-Dimethylpyrazole phosphate (DMPP) was detected as a nitrification inhibitor with widely interesting effects for long term effect of nitrogen fertilizer efficiency. By reduced nitrogen leaching, the nitrogen efficiency is increased and this has a significant effect on yield and quality.

This study was to investigate the effect of commodity nitrogen fertilizer and nitrogen fertilizer with DMPP inhibitor on seed yield and quality parameters in winter wheat. Selimiye, a bread wheat winter variety was subjected to 3 different treatments (T):

T 1) No fertilization; T 2) Local fertilization standard (Ground application: 200 kg 20-20-0/ha; Two top applications: 150 kg Urea + 150 kg AN33%= 160 kg N/ha); T 3) nitrogen fertilization with DMPP inhibitor (ENTEC Fertilizer; Ground application: 300 kg/ha ENTEC 25-15-0; Only one top application: 340 kg/ha ENTEC 26=160 kg N/ha) in four replications. The results demonstrated that nitrogen with DMPP inhibitor had a significant effect on the seed yield (T1: 4,8 t/ha < T2:7,5 t/ha< T3:7,7 t/ha). There were no significant changes of quality characteristics such as protein content, sedimentation value, gluten, gluten index and seed hardiness to observe. Further benefits of this inhibitor are, to reduce the number of top applications and application costs, as well as nitrogen leaching in order to protect the environment.

The study effect of foliar application some micronutrient on the yield and yield components on varamin variety cotton

Vahid Jajarmi,Afrooz Kolahdoozian

Bojnourd Branch, Islamic Azad University, Bojnourd – IRAN, Vahid_jajarmii@yahoo.com

Introduction

Cotton is one of the most important and worthiest products agriculture that planted in more than 100 countries and economic of some countries depends on it. Cotton is famous to white golden. Cotton (Gossypium hirsutum L.) is an important fiber crop in Iran, cultivated among the five major oil seeds, cotton seed is the second most important one. Plants can absorb a small amount of nutrients from dilute solutions sprayed on to the leaves. Since the amount of micronutrients needed by plants is very small, these can be as foliar sprays. Plants can also absorb macronutrients through the leaves, but it is not possible to supply sufficient amounts in this way, these must be taken up by the roots. Foliar application of macronutrients can help plants recover from temporary stress due to moisture problems, pests or disease.

Material and method

In order to study the effect of foliar application on yield and yield components on cotton, an experiment was conducted in factorial form, using complete block randomized design with four replications. In this experiment. Varamin variety (this cultivar had highest yield according the pervious experiment that the author had done) planted and treats were evaluated. Factor A was including five foliar application micronutrients Marker, K+S(Solopetas)2.5/1000, Zn (Zn sulfate with 14% Zn) 1.5/1000, Mn (Mn sulfate with 26% Mn)1.5/1000 , (Cu + Fe + Zn)1.5/1000. Factor B was containing: five phases of growing (Branching, Flowering initiation, Flowering ending, Branching +Flowering initiation, Flowering initiation +Flowering ending). Each plot was involving six rows with six meters in length.

Result and discssion

The result showed that the highest LIA obtained from foliar application by Zn (at every 2 times measured). The highest dry wight belong to Mn(210.46 gr/m^2) and Zn (206.60 gr/$m^{2)}$. Role of Zn is increases of yield componant such as dry weight. The highest yield (vash weight) obtained by Mn foliar application. The effect of foliar application was significant in 1% level probability. The biggest chlorophyll content belong to Mn with 47.375 SPAD at avarage two times. There is significant relationship between the number 0f pod and size it. The highest leaf area index obtained by sparing micronutrient at branching+initation flowering+end of flowering with 3.10 and the lowest leaf are index belong to no soaraing (marker). The result of Tble 3 showed that the maximum yield (vash weight) belong to sparaing at branching+initiation flowering stage, with 184.2 and 188.87gr/m^2.The lowest belong to no spraing and endof flowering.

Conclusion

The study shows that MN treatment has had the highest effect upon the important agronomy traits after which (ranking second) is the combined treatment of Fe, Zn and Cu.

Based upon the analysis of variances, none of the treatments had any effect on leaf area index at the first time.

Refrence

Banks, L,W.(2004). Effect ot timing of foliar application on yield component of soybeans.Australian Journal of Experiment Agriculture and Animal Husbandry.22(116):226-233.

Screening for macro-nutrient uptake efficiency of some vegetables under low mineral fertilizers input condition.

Ahmed Glala[1]*, Aboelftouh Abdalla*[1]*, Said Saleh*[1]*,*
Mohamed Zaki[2]*, Nadia Omar*[2]*, Mostafa Abou El-Magd*[2]

[1]*Horticultural Crops Technology Dept. and* [2]*Vegetable Research Dept., National Research Center, Dokki, Giza, Egypt, B Pox: 12311., aaa.glala22@gmail.com*

Several field trials were carried out in Egypt, during 2004 - 2012 years, on different growth pattern vegetables crops genotypes i.e., Tomato, Squash, Broccoli and Celery". In order to screen the efficiency of some cultivated genotypes of the investigated crops, in macro-nutrient uptake under partial or complete replacement of mineral nitrogen fertilizer by poultry manure or compost, associated with enrichment by bio-agent which promote root growth "PGPR" or fixing atmospheric nitrogen "NFB" i.e., *Bacillus subtilis, B. circulans; B. megaterium, Azosprillum brasilense, A. lipoferum, A. onazonense* or *Azotobacter chroococcum*. At the most critical growth stage "flowering stage" of each crop, the macronutrient contents were determined.

Results showed that genotypes and crop growth pattern type significantly affected nutrient uptake efficiency under low mineral nitrogen fertilizers input condition. In addition crop types, cultivar and bio-agent types are also playing role in plant nutrient status under different replacement ratios. However root rhizosphere enrichment by PGPR or NFB significantly increased the possibility to minimize synthetic nitrogen fertilizers inputs with no or less effect on plant nutrient status.

Generally depending on crop growth pattern, genotypes and bio-agent enrichment, results indicated that 50 - 75% of mineral nitrogen fertilizers requirement could be replaced by secondary agricultural products source "organic manure" without any significant decreases in plant nutrient contents at the most critical growth stage,

Further studies should be carried on the effect of short and long run of synthetic fertilizers alternation by organic and/or bio fertilizers on soil fertility, microbial count figures in root rhizosphere and cultivated plant nutrient status. The antagonism or synergism interaction among the different bio-agents and its effect on plant nutrient status under complete replacement "100%" of mineral nitrogen fertilizers also need further investigations. Additional breeding effort is required to improve more nutrient use efficient and more compatible with useful rhizosphere microorganism and genotypes.

Impending to minimizing synthetic fertilizer inputs in different vegetable cultivation system.

Ahmed Glala[1]*, Shaimaa, El-Sayed*[1] *and Safia Adam*[2]

[1]*Horticultural Crops Technology Dept. and* [2]*Vegetable Research Dept., National Research Center, Dokki, Giza, Egypt, B Pox: 12311., aaa.glala22@gmail.com*

Several field trials were carried out in Egypt, during 2004 - 2012 years, on different genotypes of some daily used vegetables crops i.e., Tomato, Squash, Broccoli and Celery. In order to investigate the possibility to maintain these crops productivity under partial or complete replacement of mineral nitrogen fertilizer by secondary agricultural products i.e., Poultry manure or vegetables canopy compost, associated with enrichment by plant growth promoting rhizosphere-bacteria "PGPR" or atmospheric Nitrogen fixation bacteria "NFB" i.e., *Bacillus subtilis, B. circulans; B. megaterium, Azosprillum brasilense, A. lipoferum, A. onazonense* or *Azotobacter chroococcum*.

Results strongly indicated that genotypes "cultivars" significantly affected each crop response for partial or complete replacement of mineral nitrogen fertilizers. In addition the crop growth pattern are also playing role in determine the best replacement ratio without productivity losses. Moreover root rhizosphere enrichment by PGPR or NFB significantly increased the possibility to minimize synthetic nitrogen fertilizers inputs in fruit bearing, sprout and leafy vegetables.

Generally results indicated that 50 - 75% of mineral nitrogen fertilizers regime could be replaced by natural source without any economic losses in vegetables cultivation, depending on crop growth pattern, genotypes and bio-agent enrichment.

Further studies should be carried on the antagonism or synergism interaction between he investigated bio-agents and its effect on complete "100%" replacement of mineral nitrogen fertilizers. Additional breeding effort is required to improve vegetable cultivars could produce economic production under complete organic nitrogen fertilization strategies.

Response of product quality of different vegetables types to organic fertilization and bio-agents enrichment

Ahmed Glala[1], Mohamed Ezzo[1], and Yomna Helmy [2]

[1]Horticultural Crops Technology Dept. and [2]Vegetable Research Dept., National Research Center, Dokki, Giza, Egypt, B Pox: 12311., aaa.glala22@gmail.com

Several field trials were carried out in Egypt, during 2004 - 2012 years, on different genotypes of some daily used vegetables crops i.e., Tomato, Squash, Broccoli and Celery. In order to investigate the response of fruit quality and its related health components to partial or complete replacement of mineral nitrogen fertilizer by secondary agricultural products i.e., poultry manure or vegetables canopy compost, associated with inoculation with individual or mix bio-fertilizers agents. Essential fruit physical proprieties and its health related components i.e., vitamins, taste and volatile oil were measured and determined.

Results revealed that the fruit quality characters and its essential contents and positively responded to partial or complete replacement of mineral nitrogen fertilizers. Since both fruit health related components and physical proprieties were significantly improved with minimizing mineral fertilizer application. In addition the response of genotypes to organic alternation ratios and bio-agent types gave a very clear indication toward previous direction.

Further studies should be carried on vegetables fruit response taste, aromatic components of and its compatibility with consumer preference for organic and bio-fertilizers agents.

Gluten quality-efficiency – A new breeding trait for wheat

Ludger Linnemann

Department of Organic Farming - Institute of Agronomy and Plant Breeding II, Justus-Liebig-University, Karl-Glöckner Str. 21C, D-35394 Gießen, Germany, ludger.linnemann@agrar.uni-giessen.de

Introduction

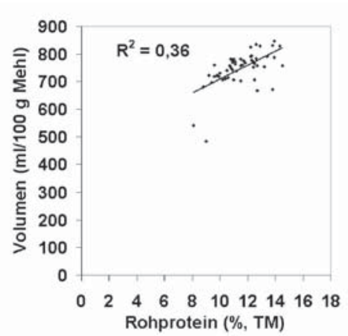
Baking quality as a breeding feature is of outstanding importance for wheat breeding. The most important parameter for the direct characterization of the baking quality is the bread-volume, which is determined in the german standard baking test (RMT). Recently, an optimized baking test was introduced, which reflects the potential of the mainly genetically fixed gluten-protein quality. Taking into account the gluten quality as a new breeding trait it is possible to select sustainable varieties with high bread-volume and low N demand.

Material and methods

The investigated wheat samples were obtained from 9 varieties organically grown at three locations in Germany (2008 and 2009). The protein concentration of flours (nitrogen % x 5.7, dry matter) was determined according to the Dumas method. The optimized baking test is discribed in detail in Linnemann (2010).

Results and discussion

In figure 1 it is shown that it is possible to get very high bread-volumes of > 660 ml/100 g flour with only 9.6% flour protein. Previously, it was assumed that for 660 ml (RMT) about 14% flour protein are required by the millers in Germany. The commonly used N-efficiency is therefore not a valuable breeding feature for sustainable agriculture. In fact, the currently available varieties differ with regard to the gluten-protein quality substantially. This offers the chance to introduce protein quality (ml volume/protein %) as new breeding trait. In the right figure wheat samples differing in gluten quality are shown. It is evident, that very high volumes >660 ml do not need high protein % but high gluten quality. This is underlined by the very weak relationship between bread-volume and flour protein (left graph).



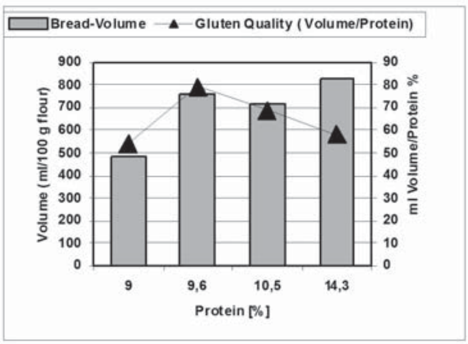


Figure 1: Relationship between crude protein and bread-volume (left). Bread-volume and gluten-quality of different wheat flours at different protein-levels.

References

Linnemann L. (2010): Entwicklung einer prozessnahen Diagnostik der Mehlqualität und Teigbereitung zur optimierten Herstellung von Backwaren aus Öko-Weizensorten. www.orgprints.org/18758/.

Preliminary results: Macro-nutrient, secondary nutrient, micro-nutrient, and trace element contents in grains of selected maize hybrid and open-pollinated varieties

W. Froelich[1], H. Burger[2], H. Kurz[3]

[1]Agrar- und Umwelt-Innovationen, Sachsenheim/Württ., Walter.Froelich@gmx.net,
[2] KWS SAAT AG, Einbeck.,
[3]Landesanstalt für landwirtschaftliche Chemie, Stuttgart-Hohenheim

In a first approach, mineral nutrient and trace element contents in the dry matter (DM) of (untreated) grains of maize hybrid and open-pollinated varieties are determined.

Mean values of eight genotypes, the respective variation coefficients and selected correlation coefficients are presented and discussed, especially for mineral nutrients which are regularly applied in mineral fertilization formulae.

Mean values for the *macro-nutrients* nitrogen N, phosphorus P, and potassium K were 1.56, 0.27, and 0.31 % of DM, respectively. The *secondary nutrients* sulphur S, magnesium Mg and calcium Ca showed mean values of 1026, 1173, and 33 mg/kg of DM, respectively. For the *micro-nutrients* iron Fe, manganese Mn, copper Cu, and zinc Zn, mean values of 19.0, 4.9, 1.1, and 18.2, respectively, were obtained. The ("ultra") *trace elements* molybdenum Mo, nickel Ni, and chromium Cr showed mean values of 0.17, 0.15, and 0.19 mg/kg of DM, respectively.

Variation coefficients obtained were low for macro-nutrients, high for secondary and for micro-nutrients, and very high for trace elements: between 5 and 10 % for N, P, K, S, and Mg – nutrients which are also considered in fertilizer application; between 10 and 30 % for Ca, Fe, Zn, Cu; and 30 to 70 % for the trace elements Mo, Ni, and Cr.

Positive correlation coefficients were observed between the contents of N and the other macro-nutrients P (r=0.73) and K (r=0.82), also between P and K (r=0.71).

Positive correlations were also found for P and S (r=0.52) and P and Mn (r=0.62), as well as for Mg with N (r=0.53), P (r=0.81), and K (r=0.53).

Negative correlation coefficients showed Ca with N (r=-0.74) and P (r=-0.73).

The well-known *Ca/Mg antagonism* was proven by a negative correlation coefficient (r=-0.55), too. It is well known that calcium plays a special role in both regulating soil acidity and as a plant nutrient.

All the four micro-nutrients showed more or less strong correlations with various other elements, as well as the trace elements Mo and Cr.

Finally, the function of the trace elements molybdenum Mo, nickel Ni, cobalt Co, and selenium Se which are essential for biogas plant bacteria is briefly outlined.

These *Archaea* play a basic role in methanogenesis processes.

With few exceptions, these quantitative findings are in accordance with qualitative results as reported by soil scientists, plant and animal nutritionists.

Evaluation of nutritive value of chosen fodder crop species in depending on nitrogen fertilization level in low-input system conditions

Jolanta Bojarszczuk

Institute of Soil Science and Plant Cultivation – State Research Institute, Department of Forage Crop Production, Czartoryskich Str. 8, 24-100 Puławy, Poland,
e-mail: Jolanta.Bojarszczuk@iung.pulawy.pl

Introduction

The aim of the study was to evaluation the nutritive value of maize, sorghum, rye, triticale and topinambour, cultivated on light soil in differentiated nitrogen fertilization level, in low-input system conditions.

Material and methods

The field split-plot experiment was carried out in the years 2008–2010, by subblock method in four repetitions in Experimental Station. The crop species (‘Anjou 290’ maize, ‘Sucrosorgo 506’ sorghum, ‘Diament’ winter rye, ‘Krakowiak’ winter triticale, ‘Albik’ topinambour) was the first factor and the second factor was nitrogen fertilization level (kg·ha^{-1}): maize and sorghum - N1 – 80; N2 – 120; N3 – 180; rye, winter triticale and topinambour - N1 – 40; N2 – 80; N3 – 120. The evaluated crop species was cultivated on silage using. The content of dry matter, protein, crude fat, crude fibre, crude ash and digestibility (by enzymatic method) have been determined. Moreover the content of main macro elements as: P, K, Mg, Ca have been determined also. The silage from crops (maize and sorghum) fertilized by 120 kg·ha^{-1} nitrogen dose and from other crops (rye, triticale, topinambour) fertilized by 80 kg·ha^{-1} nitrogen dose, have been prepared.

Results

The results of this experiments showed that dry matter digestibility of maize was at about 20% higher than digestibility of sorghum and rye and at about 10% higher than digestibility of triticale and topinambour. The increased nitrogen fertilization of cereals and topinambour limited the digestibility of their dry matter and caused the less gathering of fat. The increased nitrogen fertilization had not significantly influence on content of Mg, Ca and P accumulation of crude fibre in maize, sorghum, rye and triticale and digestibility of maize and sorghum. The largest content of protein in topinambour have been observed in the second and third year of cultivation and the lowest content of this element characterized topinambour in the first year (year of seeding). The evaluated crops characterized very similar mean content of crude fat in dry matter and the biggest content of ash characterized the topinambour crops. The results showed that crops of rye, triticale and topinambour content significantly more P than crops of sorghum and maize independently on nitrogen fertilization level. The biggest concentration of K, Ca and Mg characterized the topinambour crops in the second and third year of cultivation independently on harvesting term. In the first year of cultivation (2008) content of crude fat and protein in silage made of evaluated crop species were higher than in green matter. Moreover, the concentration of crude fibre was higher in silage made of triticale, however concentration of crude ash was higher in silage made of maize and triticale.

Dry matter, Mg and P content in silage from all evaluated species was very similar as in source material, however content of Ca and K in silage of all evaluated species, the crude fibre in silage from maize, triticale, rye an topinambour, ash in sorghum and topinambour showed that its concentration was less than in green matter.

Content of anti-nutritional substances in legume seeds depending on cultivar and region of cultivation

Jerzy Księżak

Department of Forage Crop Production, Institute of Soil Science and Plant Cultivation –State Research Institute, Czartoryskich 8, 24-100 Pulawy, Poland, Jerzy.Ksiezak@iung.pulawy.pl

An important feature of legumes is that they contain substances that effect negatively the utilization of nutrients called anti-nutritional or anti-nutritive factors and compounds acting as growth depressing factors at animals. Anti-nutritional constituents have or may have a detrimental effect on a nutritional, technological and sensory value of seeds or products derived from them. Their presence reduces the full use of the high quality protein of legume seeds. The study was aimed to determining the effect of agro-environmental conditions on the content of anti-nutritional substances in the seeds of legumes and at identifying the relationships between their content and the content of important nutrients.

The impact of agro-environmental conditions on the concentration of anti-nutritional substances was evaluated on the basis of the material derived from the experiments located in different parts of Poland in low-input farms. The seeds of faba bean and pea cultivars were marked for the content of tannins, yellow and blue lupine for the sum of alkaloids, and yellow lupine also for the content of gramine. Moreover, the seeds of all species were marked for major nutrients.

Tannins constitute important compounds in the seeds of different cultivars of faba bean and pea. They cause a lower digestibility of protein and carbohydrate, reduced availability of methionine and iron and impair the taste of the feed. The pea cultivars: Marych and Muza contain a significantly lower number of these compounds. More of them can be found in Roch and Wiato cultivars. In the southern part of the country seeds of pea cultivars accumulated significantly less of these compounds and significantly more in the western part of Poland. The amount of tannins was not significantly differentiated by agronomic factors or protein and fiber content in seeds. Seeds of white-flowered faba bean cultivars, such as Leo, Kasztelan, Albus, Amulet, Olga were characterized by a smaller amount of these compounds. Their higher amount was found in Bobas, Sonet, Granit and Optimal. The tannin content of faba bean seeds was significantly negatively correlated with total protein and fiber content. The area of cultivation as well as agronomic factors had no significant effect on the concentration of these substances. The alkaloids found in seeds of yellow and blue lupine may act as stimulants, anesthetics and even poison. They affect the central nervous system, cause paralysis and can cause a severe stomach pain and vomiting. Consumed in small quantities, they decrease food intake and growth of animals. Seeds of yellow lupine cultivars Mister and Dukat contained significantly more of these compounds, and Parys - significantly less. In the north-east region of Poland, seeds of yellow lupine accumulated much less alkaloids and in the western region significantly more. The amount of alkaloids in the seeds was positively correlated with the contents of sugars, soil complex and soil reactivity.

Gramine is the compound which adversely affects animal organisms, especially if present in large quantities. All the evaluated cultivars of yellow lupine contained a small amount of this compound. The area, in which lupines were grown, had no effect on the level of the alkaloid in the seeds. Its amount was not correlated with any of the examined factors and nutrients. Among the evaluated cultivars of blue lupine, the highest amount of alkaloids was found in Mirela and Karo cultivars. At other cultivars it was significantly lower. Seeds of this species grown in the center of the country are characterized by a lower concentration of these compounds. It is significantly higher in the north of Polnad. The amount of rainfall during the vegetation season and soil pH did not affect the accumulation of alkaloids in the seeds of blue lupine and their amount was negatively correlated with sugar content, and positively with protein content.

Composite Cross Populations of Cereals in Practice: Arguments and Recent Developments in the Legal Framework Revision

Martin S. Wolfe, Sally A. Howlett, Nick Fradgley,
Louisa R. Winkler, Bruce D. Pearce, Thomas F. Döring

The Organic Research Centre, Elm Farm, Hamstead Marshall, RG20 0HR, UK; wolfe@wakelyns.co.uk

Background

To help deal with the lack of appropriate plant varieties that are adapted to conditions of organic agriculture (e.g. Wolfe et al., 2008), the new COBRA project (Döring et al., 2013, this Symposium) aims to link breeding efforts in pure line breeding with research in the development of Composite Cross Populations (CCPs; Döring et al., 2011). In the meantime, a number of initiatives are already in progress to start this process. To allow the adoption of these approaches in practice, there is an urgent need to adapt the laws concerning varietal registration to extend beyond the current pure line constraint set by the requirement for Distinctness, Uniformity and Stability (DUS), otherwise any form of seed trade involving CCPs will remain illegal. A reformulation of the EU seed law is currently underway. In consultations, European stakeholders have reported satisfaction with the principles underlying the existing Directives but supported simplification and consolidation: thus, the new system as proposed would resemble the present one in many details. However, there is a proposed article, 15 (3), which introduces a space for additional rules allowing production and marketing of varieties not on the Common Catalogue. This means that the Commission could adopt further measures through delegated acts in future years which would allow propagation and marketing of varieties in addition to those within the previous system which do not conform to DUS.

Approach

A series of meetings and discussions involving members of the EU FP7 SOLIBAM (Strategies for Organic and Low Input Breeding and Management) project is in progress with officials in the EU to try to adapt the legal framework with respect to CCPs. In particular, rigorous criteria need to be defined that can replace the DUS system for CCPs. This paper reports on the current state of the discussions and will indicate the likely course and timescale for future progress. Particular focus will be put on the potential to use certified traceability as a process to enable the legal exchange of CCP seed, i.e. to provide the pedigree of a population in terms of how it was produced and its cultivation history since then. A replacement of the DUS would then be the description of the population by its parents, and how it has been maintained since the first crosses.

References

Döring, T.F., Knapp, S. Kovacs, G., Wolfe M.S. & Murphy, K. (2011) Evolutionary plant breeding in cereals – into a new era. *Sustainability*, 3: 1944-1971.

Döring, T. F., Baresel P, Borgen A., Finckh, M. R., Howlett, S. A., Ortolani, L., Pearce, B.D., Pedersen, T., Wolfe, M. S. (2013) COBRA: a new European research project for organic plant breeding. (*this Symposium*)

Wolfe, M. S., Baresel, J. P. Desclaux, D., Goldringer, I., Hoad, S., Kovacs, G., Löschenberger, F., Miedaner,T., Østergård, H., Lammerts van Bueren. E. T. (2008) Developments in breeding cereals for organic agriculture. *Euphytica*, 163: 323-346.

Agronomic performance of mixtures of pure lines and composite cross populations

Thomas F. Döring, Sally A. Howlett, Nick Fradgley, Louisa R Winkler, Martin S. Wolfe

The Organic Research Centre, Elm Farm, Hamstead Marshall, RG20 0HR, UK; tfdoering@gmail.com

Introduction

Of the different possibilities for using cereal composite cross populations (CCPs) in practice (e.g. see Döring et al., 2011), one that is under trial compares the performance of different mixtures of wheat pedigree line varieties with a CCP. Such a variety/population mixture could improve the performance of both the population and the variety, i.e. by complementing the ecological advantages of diversity with those of monocultural performance. To test this hypothesis we conducted field trials over 2 years at one organic and one conventional site in England. In particular, we (i) compared a CCP developed at the Organic Research Centre in field trials to two widely used wheat varieties and (ii) asked whether mixes of the CCP and the pure lines would behave differently from the predicted performance of the individual components of these mixtures.

Material and Methods

Field trials with three replicates and randomized complete block design were run at Wakelyns Agroforestry (organic) and Morley Research Station (conventional), East Anglia, UK in 2010/11 and 2011/12. Entries were (1) the YQ CCP, derived from 20 parent varieties; (2) cv. Alchemy; (3) cv. Solstice; (4) a mix of YQ and Alchemy in the ratio of 1:2; (5) a mix of YQ and Alchemy in the ratio of 2:1; (6) a mix of YQ and Solstice in the ratio of 1:2; and (7) a mix of YQ and Solstice in the ratio of 2:1. Assessments included plant density at establishment; foliar diseases on flag leaves; average, minimum and maximum plant height (from 30 plants per plot); grain yield; average ear length; thousand grain weight, and weed cover.

Results and Discussion

Statistical analyses showed that the CCP was not significantly different from the two pure lines in terms of ear length, grain yield and thousand grain weight. However, as expected, the CCPs were significantly taller than the pure lines. Establishment tended to be better in the CCP than in the two pure lines. Variability of grain yield across the 4 trials decreased consistently with increasing proportion of the CCP in the mix, being lowest in the CCP itself and highest in the pure lines. Foliar disease severity was higher in Solstice than in the CCP but was not different between CCP and Alchemy. Regarding most parameters, the mixes between the CCP and the pure lines (entries (4) to (7)) were not significantly different from expectation, i.e. from the ratio-weighted average of the individual components. The main exception was a highly significant increase in the maximum plant height in the mixtures compared to the respective components, suggesting that the mixtures might be more strongly affected by competition for light. If this predictability of performance is a general result for such mixtures, then the choice of mixing ratio for the farmer could depend simply on his/her level of risk aversion. It may be, however, that mixtures of other varieties and populations behave differently.

References

Döring, T.F., Knapp, S. Kovacs, G., Wolfe M.S. & Murphy, K. (2011) Evolutionary plant breeding in cereals– into a new era. Sustainability, 3: 1944-1971.

Food value of winter wheat Composite Cross Populations: baking quality and micronutrients

Louisa R. Winkler, Thomas F. Döring, Sally A. Howlett, Martin S. Wolfe

The Organic Research Centre, Elm Farm, Hamstead Marshall, RG20 0HR, UK, tfdoering@gmail.com

Introduction

Genetically diverse composite cross populations (CCPs) of wheat are attracting interest due to their potential resilience in fluctuating climatic conditions, under disease pressure, and in organic and low-input systems (Döring et al. 2011). Their success, however, will also depend on their performance as ingredients in food products such as bread, both in terms of functional properties and nutritional value (e.g. Pomeranz 1990). In a previous study, we found that the addition of high yielding varieties as parents to a pool of parents characterised by high baking quality did not dilute the baking quality of the resulting population. Also, CCPs were found to perform acceptably in different bread-making processes compared to commercial controls (Winkler et al. 2013). Here we ask whether wheat genetic diversity impacts on the ability of the crop stand to accumulate micronutrients.

Material and Methods

'Yield-Quality' (YQ) and 'Quality' (Q) populations (called YQCCP and QCCP) and a pure line control (cv. Solstice) were grown on an organically managed site; in addition, the YQCCP was grown on a conventional site. Both sites were located in the East of England. One organic and one conventional UK grown grain sample (pure lines) were used for benchmarking. Chemical analyses on whole grain samples (harvest 2012) were performed to determine accumulation of eight minerals of nutritional value (Mg, Ca, Cr, Fe, Co, Zn, Se, Mo) and one contaminant (Cd).

Results and Discussion

The YQCCP and QCCP were not significantly different from each other in their accumulation of minerals, with the exception of Mo, for which the QCCP showed significantly higher values (mean 1.53 mg/kg vs. 0.97mg/kg, $p<0.05$). Thus, apart from Mo, there appears to be no nutritional penalty from the inclusion of the high yielding parents in the CCP. Analysis of the YQCCP grown at two sites revealed significant site effects on Fe, Se and Mo. Compared with pure-lines (i.e. Solstice and the benchmark samples), the two CCPs showed higher micronutrient values with regard to Mg ($p<0.005$) and Zn ($p<0.05$). Although these results, drawn from a small dataset, can only be considered preliminary, further research is merited to test the impact of genetic diversity on micronutrient contents in wheat.

References

Döring, T.F., Knapp, S. Kovacs, G., Wolfe M.S. & Murphy, K. (2011). Evolutionary plant breeding in cereals– into a new era. Sustainability, 3: 1944-1971.

Winkler, L.R., Pearce, H., Fradgley, N., Döring, T.D., Howlett, S.A., Whitley, A. & Wolfe M.S. (2013). Baking quality of two winter wheat CCPs in the UK. In: Döring, T.F., Howlett, S., Winkler, L.R., Wolfe, M.S. (Eds.): International Symposium on Evolutionary Breeding in Cereals. Aston University, Birmingham - 21 January 2013.

Pomeranz, Y. (Ed.) (1988). Wheat, Chemistry and Technology. 3rd Edition. Vol I and II. American Association of Cereal Chemists (AACC, 3340 Pilot Knob Road, St. Paul, MN 55121, U.S.A.),. Vol. I: 562 p: Vol. II: 514p.

COBRA: a new European research project for organic plant breeding

Thomas F. Döring[1], Peter Baresel[2], Anders Borgen[3], Maria R. Finckh[4], Sally A. Howlett[1], Livia Ortolani[5], Bruce D. Pearce[1], Tove Pedersen[6], Martin S. Wolfe[1]

[1]The Organic Research Centre, Elm Farm, Hamstead Marshall, RG20 0HR, UK; tfdoering@gmail.com , [2]Technical University of Munich, Department of Crop Science, Emil-Rahmann-Str. 2, 85354 Freising, Germany; [3]Agrologica, Houvej 55, 9550 Mariager, Denmark; [4]University of Kassel, Department of Ecological Plant Protection, Nordbahnhofstr. 1a, D-37213 Witzenhausen, Germany; [5]AIAB, Via Piave, 14 - 00187 Roma, Italy; [6]Knowledge Centre for Agriculture, Agro Food Park 15, 8200 Aarhus N, Denmark.

Background

One of the obstacles to the successful development of organic farming systems is the lack of appropriate plant varieties that are adapted to conditions of organic agriculture (e.g. Wolfe et al. 2008). For resolving this issue plant breeding efforts for organic systems need to be better coordinated. In addition, using greater plant material with higher genetic diversity has great potential in breeding for these systems. Crop genetic diversity is particularly important in organic agriculture because germplasm suitable for organic conditions often stems from management systems that do not use synthetic inputs. Also, higher levels of in-field diversity can be used to buffer against the relatively high environmental variability in organic systems.

Approach

In conjunction with the need to breed specifically adapted pure line varieties for organic crop production, a complementary approach is the use of plant material with High genetic Diversity (Hi-D) e.g. as in Composite Cross Populations (CCPs) (Döring et al. 2011). Apart from buffering against environmental fluctuations and providing insurance in stressful environments, Hi-D-based approaches allow for evolutionary adaptation to organic farming conditions. However, despite the promising results Hi-D-based systems have shown under organic management, their benefits cannot be used at present due to agronomic, technical and regulatory hurdles. These constraints of Hi-D breeding approaches are shared with and linked to organic plant breeding in general. A new European research project called COBRA (Coordinating Organic plant Breeding Activities for Diversity) aims to unleash the potential of plant genetic diversity for organic agriculture by linking up efforts on both pure line breeding and Hi-D systems. The project, led by the Organic Research Centre (UK), started in March 2013 and brings together 41 partner organizations from 18 countries. COBRA focuses on four major arable crops: wheat, barley, pea and faba bean. It will address five specific areas: (1) seed health; (2) response of crops to multiple stresses; (3) improvements in breeding efficiency for organic systems; (4) structural issues such as funding for breeding and the regulatory framework; and (5) networking and coordination. This paper describes the background to the project and introduces its unifying concepts.

References

Döring, T.F., Knapp, S. Kovacs, G., Wolfe M.S. & Murphy, K. (2011) Evolutionary plant breeding in cereals– into a new era. *Sustainability*, 3: 1944-1971.

Wolfe, M. S., Baresel, J. P. Desclaux, D., Goldringer, I., Hoad, S., Kovacs, G., Löschenberger, F., Miedaner,T., Østergård, H., Lammerts van Bueren. E. T. (2008) Developments in breeding cereals for organic agriculture. *Euphytica*, 163: 323-346.

Analysing stability of yield and quality parameters in winter wheat variety mixtures for organic farming in Austria

Franziska Löschenberger[1] and Almuth Müllner[2]

[1]Saatzucht Donau GmbH, Saatzuchtstrasse 11, A-2301 Probstdorf, franziska.loeschenberger@saatzucht-donau.at, [2]BOKU / IFA, Konrad-Lorenz Strasse 20, A-3430 Tulln

Introdcution

Greater stability of variety mixtures compared to single variety performance has often been reported, but mixtures have not yet found their way into the organic seed market in Austria. Stimulated by the framework of the COST action 860 SUSVAR (Sustainable low-input cereal production: Required varietal characteristics and crop diversity), Saatzucht Donau GmbH (SZD) performed variety mixture trials at its main organic testing location Dörfles in Austria over 3 years. 6 premium quality winter wheat varieties were divided into two groups of 3 varieties each, which are exclusively marketed by the two SZD shareholders, Probstdorfer Saatzucht and Saatbau Linz. Group 1 consisted of *Capo, Bitop, Pireneo* and the respective two-way-mixtures; group 2 consisted of *Saturnus, Stefanus, Antonius* and the respective mixtures. In particular, we were interested in differences between varieties and variety mixtures regarding grain and protein yield potential and stability.

Results

For grain yield, analysis of variance revealed significant differences between genotypes and environments: Yield for *Capo* was lower compared to any other genotype; *Stefanus* had a lower yield compared to the mixture *Antonius-Stefanus*. Stability analysis was based on the concept of ecovalence (and regression analysis) one the one hand and AMMI and GGE biplot analysis on the other hand. Different tools revealed similar trends: *Bitop, Capo* and *Pireneo-Capo* had the highest ecovalence values and therefore lowest stabilities; of these, *Bitop* was also the one with the lowest yield. This result was confirmed by AMMI and GGE biplot analysis. The lowest values for ecovalence, and therefore highest stabilities, were observed for *Pireneo, Bitop-Pireneo,* and *Antonius-Saturnus*; AMMI analysis for grain yield suggested that the two most stable (and also highest yielding) genotypes were variety mixtures: *Bitop-Pireneo, Antonius-Stefanus*, and *Pireneo.* GGE biplot analysis supported these results and in addition suggested that the 3 most favourable genotypes (with reference to the ideal environment) were variety mixtures. Overall, mixtures compared to pure lines as groups showed a greater stability than pure lines.

For protein yield, which offers a simple means to study nitrogen efficiency, data were only available for two years: As for grain yield, no major differences between varieties and variety mixtures in protein yield could be detected. With regard to stability, *Bitop-Pireneo, Pireneo* and *Pireneo-Capo* were the winners and also the highest yielding one. The least stable genotypes were *Stefanus, Saturnus-Stefanus* and *Antonius-Stefanus*.

Outlook

In autumn 2011, a new round of the variety mixture trial started, comprising recent SZD variety releases and breeding lines for organic agriculture; hopefully, data coming from this set of trials will help to identify variety mixtures which are of interest to the organic seed market in Austria.

The need for breeding for cereal legume combinability: experiences in The Netherlands

Udo Prins, Edwin Nuijten

Louis Bolk Instituut, Hoofdstraat 24, 3972 LA Driebergen, The Netherlands; e.nuijten@louisbolk.nl

Particularly for organic farming, mixed cropping of cereal and legume crops can provide advantages in terms of nutrient use efficiency, weed suppression and more stable yields. Cereals benefit from the nitrogen fixing ability of legumes, which also result in higher protein levels in the cereal crop, improving its quality as fodder and potentially also as food. Grain legumes benefit from the reduced weed pressure in cereal crops. In the past 10 years, various combinations of cereal (particularly wheat, barley, oats and triticale) and legume (faba bean, peas and lupins) crops have been tested by the Louis Bolk Institute. To optimise the crop mixtures, each combination requires specific traits of the cereal and legume crop. So far, breeding has focused on mono-cropping. Including traits important for mixed cropping will improve the potential of mixed cropping. For example, peas are normally mixed with barley because of simultaneous ripening. However, both crops are very prone to lodging. Mixing peas with wheat could improve the performance but peas ripen too early for most wheat cultivars. An earlier ripening wheat or a later ripening pea could make an ideal combination. In crop mixtures with faba beans the undetermined growth of faba bean is a problem in some years. A somewhat taller and later ripening wheat could make a better crop mixture with faba bean. In this poster we describe the advantages of each cereal legume combination and the traits on which breeding is needed to optimise its potential.

Forage quality of legume-cereal mixtures depending on the composition and share of components

Mariola Staniak

Institute of Soil Science and Plant Cultivation – State Research Institute, Department of Forage Crop Production, Czartoryskich Str. 8, 24-100 Puławy, Poland, Mariola.Staniak@iung.pulawy.pl

Introduction

Cultivation of legume-cereal mixtures is advisable due to the production and agronomic value. They complementarily use habitat resources and there are compensational growth and development of the cultivated species. Additionally, the higher level of total protein and lower NDF (Neutral Detergent Fiber) content clearly showed the advantage of using such mixtures. Chemical composition and nutritive value of seeds yield depend on number of factors. The aim of the study was to evaluation the feed quality of legume-cereal mixtures depending on the composition of mixtures and share of seed components at sowing.

Material and methods

The field split-plot experiments were carried out in the years 2010–2012, in split-plot system, with 4 replicates, in organic farm. Three mixtures of blue lupine (*Lupinus angustifolius* L.) with spring cereals: wheat (*Triticum* L.), triticale (×*Triticosecale* Wittm. ex A.Camus) and barley (*Hordeum* L.) were compared. The share of legume seeds in mixture was: 40, 60 and 80%. The density of plants in pure sowing, used as the base to calculate their density in the mixtures, was as follows (units·m^{-2}): lupine – 100, wheat – 500, triticale - 500, barley – 300. Seeds were sown at the first or second decade of April. Plants were harvested at full maturity stage of mixture components at the first or second decade of August. The contents of major nutrients and macronutrients were determined.

Results

The results of this experiments showed that the increasing the percentage of legume seeds at sowing had positive effect on the concentration of total protein and crude fat contents in the yield of mixtures. It also resulted in increase the content of crude fibre and crude ash in yield, regardless of the cereal species. The highest content of total protein and was noticed in the mixture of blue lupine with wheat (in range 20.8 – 23.5%) whereas the least was observed in mixture with barley (15.8 – 18.6%). It was similar, in case of crude fat. Feed with the highest crude fat content was obtained by cultivation of blue lupine with wheat (mean 3.75%), while the least of this component was found in mixture with barley (2.82%). The percentage of legume seeds in mixture had little influence on the content of phosphorus (in range 0.35 – 0.48), calcium (0.14 – 0.27%) and magnesium (0.16 – 019%). The increasing of potassium concentration in fodder with higher share of legume seeds, regardless of the species of cereal, has been observed.

Conclusion

Feed from mixture of blue lupine with wheat was characterized with the highest content of protein and fat, whereas the least of these components were found in mixture with barley. An increase in the share of lupine at sowing favorably influenced the content of protein and fat, but also resulted in increased quantities of crude fibre, ash and potassium, regardless of the species of cereals.

Competition of interseeded cover crops and weeds in organic maize farming

Rüdiger Jung, Rolf Rauber

Georg-August-Universität Göttingen, Department for Crop Sciences, Section Agronomy; rjung@uni-goettingen.de

Introduction

Late season weeds are often recognized as threat for the main crop yield in organic maize farming. Therefore, interseeded cover crops could bear good prospects to suppress weeds in the mid and late growing season of maize. We tested several interseeded cover crops in maize trials to evaluate their potential.

Materials and Methods

Interseeded cover crops combined with three maize cultivars were grown for three years (2011 – 2013) and at two locations in Lower Saxony (Germany). Field experiments were located at Reinshof near Göttingen (51°30'N, 9°56'E) and Wiebrechtshausen near Northeim (51°44'N, 10°01'E). Soil types were silty clay loam Fluvisol (Reinshof) and silt loam Luvisol (Wiebrechtshausen). Experiments were conducted with four replicates in a randomized block design, including three maize cultivars (Colisee, Ricardinio, Ronaldinio), eight variants of interseeded cover crops ('Grasslands Puna' chicory, subterranean clover, winter rye, Italian ryegrass and buckwheat as sole crops or combined in mixtures) and two control plots. Maize cultivars were established in the early days of May. Cover crops were sown four weeks later. Until the sowing of cover crops, weed growth was constrained mechanically. Dry matter (DM) yield of weeds and cover crops were determined three times within the growing season by harvesting plots of 0.45 m². The cover crop and weed cover were recorded in 0.1 m² grids using digital camera images in two week intervals (July to October).

Results and Discussion

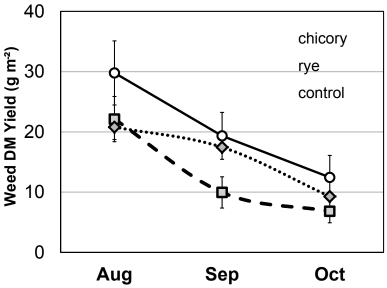


Fig. 1: Dry matter (DM) yield of weeds in chicory and rye in comparison to DM yield of weeds in control plots without cover crops. Arithmetic means ± standard error for two sites and two years (2011, 2012).

The ability for annual weed suppression varied between the investigated cover crops. Italian ryegrass and chicory showed the highest cover (mean 65 %); cover was still over 60 % in late October. In addition, the lowest levels of weed cover and weed DM yield were observed in September and October in chicory (Fig. 1). In comparison winter rye predeceased repeatedly resulting in weed regrowth. Arising from this, DM yield of weeds in winter rye nearly reached the level of the controls (Fig. 1). Biomass and cover of subterranean clover were slightly lower than those of chicory, though weed emergence was on a low level. Buckwheat revealed high levels of DM yield and a small number of weed seedlings. Plant heights about 1.0 m in buckwheat resulted frequently in undesirably lodging. In plots with cover crops, the decrease of maize grain yield seemed to be low. Weed growth in maize cultivar 'Colisee' was slightly higher than in 'Ricardinio' or 'Ronaldinio'. Our results lead to the conclusion that 'Grasslands Puna' chicory and Italian ryegrass could be recommendable for annual weed suppression in organic maize farming.

Improving energy maize with specific adaptation to intercropping with climbing beans

Christopher Hoppe[1], Walter Schmidt[2], Heiko C. Becker[1]

[1]Georg-August-Universität Göttingen, Department of Crop Sciences, Von-Siebold-Str. 8, 37075 Göttingen, Germany; [2]KWS Saat AG, Grimsehlstr. 31, 37555 Einbeck, Germany; christopher.hoppe@agr.uni-goettingen.de

Introduction

Maize (*Zea mays*) can produce a very high biomass with low production costs. Therefore today maize is not only grown for kernel and silage use, but energy maize is also the most important substrate for biogas. In Germany, the cultivation of maize for energy production increased from ca. 70.000 ha in 2005 to about 800.000 ha in 2012. However, concerns as to the loss of biodiversity due to increasing maize monocultures led to political restrictions in Germany. Since 2012 every new build biogas plant has only been subsidized if not more than 60 % of maize or cereal grain are used as substrate for energy production. One approach to increase biodiversity is the intercropping of maize with climbing beans (*Phaseolus vulgaris*). This mixed cropping system can reach yields nearly 100 % of a sole maize cropping system, although neither maize nor beans have been bred for this system (Pekrun et al. 2012). Intercropping systems are characterized by a reduced demand of N fertilizer and positive ecological effects like pollinator insects and reduced pests (Altieri et al., 1978). The objectives are to investigate the potential of a breeding program for maize adapted to intercropping with climbing beans.

Material and Methods

In 2012 field experiments at three locations (Einbeck, Göttingen, Grucking) with two replicates 200 testcross hybrids from a breeding program were grown as sole maize and in an intercropping system with the climbing bean cv. 'Neckarkönigin'. At harvest, the total biomass of the plots was measured.

Results and Discussion

The phenotypic correlation of the yields between the sole maize crop and the intercropping system was 0.72 (significant with p-value $< 2.2e-16$). This indicates that developing new varieties adapted to intercropping instead of using the present varieties can improve the yield of the intercropping system. To support this hypothesis the 20 best maize lines in each of the two systems were selected, crossed with a new tester, and are grown at three locations in 2013 as solo crop or in intercropping. In a third year of the experiment the hybrid with the highest yield together with beans in an intercropping system will be identified to make the intercropping system more competitive.

References

Altieri M. A., Francis C. A., van Schoonhoven A., Doll J.D (1978) A review of insect prevalence in Maize (Zea mays L.) and bean (Phaseolus vulgaris L.) polycultural systems. Field Crops Research, 1: 33-49.

Pekrun, C., Hubert, S., Zimmermann, C., Schmidt, W. (2012) Gemengeanbau von Mais mit Stangenbohnen – erste Ergebnisse aus Feldversuchen 2011. Mitteilungen der Gesellschaft für Pflanzenbauwissenschaften 24, S. 333-334.

Genetic Diversity of Local Varieties of Honey Sweetpotato in West Java Indonesia Based on Morphological and Agronomical Traits

Agung Karuniawan[1,] and Budi Waluyo[2]*

[1]Department of Agronomy, Padjadjaran University, Jatinangor, Indonesia 45363; akaruni1@ unpad.ac.id , [2]Department of Agronomy, University of Brawijaya, Malang, Indonesia 65145.

Sweet potatoes are a great potential as a source of food, feed, and industrial raw materials in Indonesia. Local sweet potatoes from Cilembu a pioneer non-rice food diversification as socially acceptable to be consumed immediately after steaming or oven. Characteristic of the local sweet potato Cilembu is able to produce honey or caramel similar if the oven is only generated if planted in the Cilembu. Currently around the area Cilembu widely planted sweet potatoes and similar Nirkum Eno (Karuniawan, Waluyo, Rahmannisa, & Maulana, 2011; Maulana, Waluyo, & Karuniawan, 2011). To prevent extinction and assurance continuity of production it is necessary to identify the morphological and agronomical characters of honey sweet potato.

Identification of morphological and agronomical performed to determine the diversity of local varieties and mostly done by researchers (Afuape, Okocha, & Njoku, 2011; Gwandu, Tairo, Mneney, & Kullaya, 2012; Tairo, Mneney, & Kullaya, 2008; Veasey et al., 2007). Huaman, Aguilar, & Ortiz (1999) suggest the identification of sweet potato morphology typical of an area eco-geography useful to improve the efficiency of utilization of direct and collection efforts and conservation genetics. If the identification of varieties based on morphological able to determine the different types, the production activity of honey sweet potato and sweet potato germplasm management to be effective and efficient.

Material and Methods

The research material consisted of 45 accessions of honey sweet potato. Vine cuttings obtained from Cilembu village, Pamulihan, Sumedang, West Java. Field experiments of 5 planting seasons were conducted at the Experiment Station Faculty of Agricultural Padjadjaran University, Ciparanje Sumedang West Java during 2010 until 2012. The experiments were conducted based on a randomized block design. Treatment consisted of 45 accessions of sweet potato repeated twice. One row plot of 5 m long of each accession were employed, planting distance was 20 cm apart and 100 cm between rows. The morpho-agronomical data observed consisted of 27 characters based on Bioversity International CIP (2010). Agglomerative hierarchical clustering (AHC) with proximity type similarity by Pearson correlation coefficient and UPGMA agglomerative method (unweighted pair group method with arithmetic mean) was performed to determine the genetic diversity of honey sweet potato accessions, and their GxE interaction for some traits.

Results and Discussion

Four groups of honey sweet potato accessions from Cilembu observed from 5 planting seasons were found. GxE interaction for some agronomical traits have been observed. Accessions honey sweet potatoes that have a high similarity with Nirkum and Eno can be used as a source of seed plants to increase the production of sweet potato honey. Morphological and agronomical characters can be used to identify similarities or duplications honey sweet potato accession in relation to plant breeding and the preservation of sweet potato germplasm.

More pests in organic farming conditions? The *Fusarium* case

Antonin Le Campion, Jean-Yves Morlais, Bernard Rolland, Maxime Trottet

INRA, UMR 1349 IGEPP, 35653 Le Rheu, France ; bernard.rolland@rennes.inra.fr

Three fungicide applications are commonly used to control winter wheat pathogenic fungi in high input farming system in north-west France. This practice is generally effective to control wheat leaf and ear diseases which depreciate yield and winter wheat quality. In that case, are fungal crop infections more severe and common without fungicides use in organic field crops? And how can we control pests without fungicide application especially in organic systems?

Fungal disease impact on winter wheat yield is the principal concern for farmers, but several species of *Fusarium* are also mycotoxin producers. Their ingestion may result in several more or less important human and animal health disturbances. Thus, in organic farming systems in which fungicide application is prohibited a special attention is devoted to *Fusarium* contamination and farmers are particularly interested in *Fusarium*-resistance variety.

From 2005 to 2012, sanitary quality of several batches of seed from on-farm variety trials conducted in organic conditions was determine in laboratory. The analysis was based on four fungal groups: *Fusarium*, *Microdochium nivale*, *Alternaria* and *Epicoccum*. Batches of seeds came from three locations in France: Rennes in Brittany (2005-2012), Sermaise in Ile-de-France (2005, 2007, 2008, 2010, 2011, 2012) and Lusignan in Poitou-Charente (2005, 2006, 2007). Each year, 100 seeds from 3 to 6 varieties were disposed in Petri dishes on a PDA (Potato Dextrose Agar) culture medium after superficial seed sterilization.

Seeds' contamination level was then visually evaluated. Results were compared with two control genotypes each year: Renan (no measure in 2006) was the "resistant" control variety and Caphorn the "susceptible" one.

Contamination levels were generally high for *Alternaria* (17 to 96% of seeds were contaminated) with high variability between years. They were generally low for other fungal groups: a few peaks reaching about 40% seed contaminations were denoted for *Epicoccum group*.

Fusarium contaminations were high only one year in 2008 (49% in Rennes and 18% in Sermaise) but were practically not detected among the other years. The influence of the previous crop (maize) and climatic effect with high rainfalls in the month of May are point out to explain high *Fusarium* contaminations observed in 2008.

Our results are consistent with those obtain by Champeil *et al.* (2004). Indeed *Fusarium* head blight would not be a cause of major concern for the production of winter wheat in organic farming systems. Organic farmers devoted a special attention to crop rotation and agronomic practises for the sustainability of their system. This consideration is point out to explain the low occurrence of significant *Fusarium* contamination episode in organic on-farm trials.

Champeil, A., Fourbet, J.F., Doré, T. & Rossignol, L. (2004). Influence of cropping system on Fusarium head blight and mycotoxin levels in winter wheat. Crop Protection 23: 531-537

First registration of two bread wheat varieties in the catalogue after VCU test in organic farming system in France

Bernard Rolland[1], *Laurence Fontaine*[2], *Aurélie Mailliard*[3]

[1]*INRA, UMR1349 IGEPP, 35653 Le Rheu ; bernard.rolland@rennes.inra.fr*
[2]*ITAB, 9 rue André Brouard, 49100 Angers*
[3]*GEVES – SEV, Domaine de l'Anjouère, 49370 La Poueze*

At the end of the years 1990, the request has been rising for new adapted varieties for organic farming conditions. Responding to this demand, French wheat breeders from Genetic and Plant Breeding department of INRA decided to evaluate their "hardy" breeding lines in organic conditions from 2000. We define a "hardy" genotype like a new variety, multiresistant against pests and providing relative high yields in strong environment conditions.

These inbred lines intended to be cultivated in Integrated Pest Management were selected in very low input conditions. Then, we evaluated in organic conditions their abilities to combine high yields with low nitrogen supply and high baking quality with poor grain protein contents. Just a few of them supported these two strong constraints. In the first part of the programme three INRA stations in north-west France (Lusignan, Le Moulon and Rennes) organised in a network have supervised variety on-farm trials in organic conditions during five years. The best lines were then tested in the ITAB network. This large field network (about 40 locations) was created in 2002 to evaluate new released French and European varieties potentially suitable for organic conditions. Agronomic abilities and baking quality of the two INRA inbred lines CF99102 (Skerzzo) and RE04073 (Hendrix) were screening in this network during three years. After a first failed attempt initiated in 2005 by a breeding company, ITAB network's participant and the entire French breeding sector have supported in 2009 the proposition formulated by INRA and Agri-Obtentions to set up an original registration test dedicated to organic conditions. This demand was accepted by the CTPS (French Permanent Technical Committee for the Selection of Cultivated Plants) and several VCU's (Value for Cultivation and Use) trials were lead applying the methods of the standard experimentation but also, for the first time in France, applying organic farming practises in 8 certified lands situated in north-west France.

In this original experimentation conducted by GEVES (Variety and Seed Study and Control Group) and ITAB, Hendrix and Skerzzo obtained higher yields than the two standard organic varieties, Renan and Saturnus. In the same time the two lines bred by INRA got the same baking notations than Renan, which serve as a reference for baking quality, allowing them to be inscribed in the official French catalogue with the special mention "organic farming".

This work was realized thanks to a strong collaboration between INRA and ITAB. Now the way is open in France for new organic registrations in the official catalogue, like in Austria or Switzerland. INRA's breeders are carrying on their researches to create new adapted varieties with the components waited by producers and particularly a strong ability to cover the soil to suppress weeds more efficiently.

Differences in Grain/Straw Ratio and Protein Content and Yield in Landraces and ModernVarieties of Different Wheat Species in Organic Farming

Petr Konvalina[1], Ivana Capouchová[2], Dagmar Janovská[3], Martin Káš[3], Jan Moudrý[1]

[1]University of South Bohemia in České Budějovice, Faculty of Agriculture, Studentska 13, České Budějovice, CZ 370 05, Czech Republic, konvalina@zf.jcu.cz
[2]Czech University of Life Sciences, Faculty of Agrobiology, Food and Natural Resources, Kamýcká 120, CZ 165 21 Prague 6, Czech Republic
[3]Crop Research Institute, Drnovská 507, CZ 161 06 Prague 6, Czech Republic

Introduction

Plant genetic resources are a unique non renewable resource of an improvement in the genetic base of field crops (Østergård et al., 2009). Relevant resources of diversity and strategies for an implementation of genetic diversity in organic breeding programmes have to be identified (Serpolay et al., 2011). Bread wheat is the most common food crop, but in organic farming have usually worse technological quality and lower yield. Therefore, it is supposed to be an alternative of growing hulled wheat species (einkorn, emmer wheat and spelt). The aim of our work was to analysed differences between varieties in phytomass production, share of grain/straw and relation between grain yield, protein content and yield.

Material and methods

Twenty-three landraces of different wheat species and two control bread wheat varities were grown on the certified organic parcel in České Budějovice and Prague between 2009 and 2012. After harvest were analysed protein content in grain, grain and straw yield. Data were processed in Statistica 9.0 program.

Results and discussion:

Landraces very often do not compare to the modern bred varieties of wheat in yield (Dengcai et al., 2003). It is because of assimilates in plant during the nutrient translocation stay in straw. There was worse distribution of assimilates into grain, in comparison to modern varieties of bread wheat. Many landraces had practically same phytomas yield as modern varieties. In landraces there was also higher protein content (3-6%). If we evaluated protein yield per hectar, there weren´t so big differences (some spelt varieties had protein yield per hectare higher than modern varieties of bread wheat). Some landraces of wheat can be valuable for breeding of “organic” varieties or perspective for organic farmers. Especially if they are grown in marginal areas (Marino et al., 2009).

Acknowledgement

This work was supported by the research projects No. NAZV QJ1310072 of the Ministry of Agriculture of the Czech Republic.

References

Dengcai, L., Youliang, Z., Xiujin, L. (2003).Utilization of wheat landrace Chinese Spring in breeding. Scientia Agricultura Sinica, 36 (11): 1383-1389.

Marino, S., Tognetti, R., Alvino, A. (2009). Crop yield and grain quality of emmer populations grown in central Italy, as affected by nitrogen fertilization. Eur. J. Agron. 31: 233-240.

Østergård, H., Finckh, M.R., Fontaine, L:, Goldringer, I., Hoad, S.P., Kristensen, K., Lammerts van Bueren, E.T., Mascher, F., Munki, L., Wolfe, M.S. (2009).Time for a shift in crop production: embracing complexity through diversity atall levels. J. Sci. Food. Agric. 89: 1439-1445.

Serpolay, E., Dawson, J.C., Chable, V., Lammerts van Bueren, E.T., Osman, A., Pino, S., Silveri, D., Goldringer, I. (2011). Diversity of different farmer and modern wheat varieties cultivated in contrasting organic farming conditions in western Europe and implications for European seed and variety legislation. Org. Agr. 1: 127-145.

Development of maize hybrids with high weed tolerance for organic farming systems

Mareile Stever[1], Walter Schmidt[2], Henriette Burger[2], Heiko C. Becker[1]

[1]Department of Crop Sciences, Georg-August-Universität Göttingen, Von-Siebold-Str. 8, 37075 Göttingen, Germany, mstever@uni-goettingen.de,
[2]KWS SAAT AG, Grimsehlstraße 31, 37574 Einbeck, Germany

Introduction

In organic farming maize *(Zea mays)* is not as important as in conventional farming though it would be of great interest for animal nutrition or as cash crop. But maize is not meeting the high demands of organic farming to its germination, early vigour, tolerance to nitrogen deficiency situations, and, most importantly, tolerance against weeds. The purpose of this project is to develop maize hybrids with high weed tolerance and to compare selections with and without weed pressure. A weed tolerant genotype is defined as one that shows high yield while growing with weed.

Materials & Methods

Flint and Dent material from the KWS SAAT AG (200 genotypes) was field-tested in a variant without weed and one with 'artificial weed' in 2011 at 2 locations (Göttingen and Wiebrechtshausen) in 2 replicates. The artificial weed is a mixture of buckwheat (*Fagopyrum esculentum*), rye (*Secale cereale*), and chicory (*Cichorium sp.*) that is sown to bypass the problem that naturally the weed pressure varies within one field. A subset of genotypes selected in each variant based on maturity corrected grain yield was evaluated in 2012 only in the respective variant at 4 locations in 4 replicates. From each variant 7 Flint and 7 Dent lines were selected and crossed in a factorial. These factorials are field-tested each with and without weed in 2013 at 2 locations in 2 replicates to compare selection for weed tolerant genotypes under both conditions. The field trials were under organic conditions throughout. Measured traits are early vigour, weed score, SPAD (Minolta SPAD 502), plant height, dry matter content of the grain and grain yield.

Results & Discussion

In 2011 yield, plant height and SPAD values were lower for the variants with weed. Generally the differences were higher in the Flint material. We found genotypic variation for yield in both variants for both materials. The phenotypic correlation for grain yield of the genotypes between the variants with and without weed is r=0.45 for the Flint material and r=0.74 for the Dent material and is highly significant. So the most weed tolerant genotypes we selected from the variants with weed were partly the same selected without weed. This was also true in 2012. When the factorial crosses will be evaluated in 2013 in both variants it can be clarified if it is necessary to test lines with 'artificial weed' to get weed tolerant genotypes, or if it is sufficient to select the highest yielding genotypes under normal organic conditions.

This research is funded by the Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz.

Burger, H., Schloen, M., Schmidt, W. & Geiger, H.H. (2008) Quantitative genetic studies on breeding maize for adaptation to organic farming. Euphytica 163:501-510.

Messmer, M., Burger, H., Schmidt, W. & Geiger, H. (2010). Importance of appropriate selection environments for breeding maize adapted to organic farming systems. 60. Tagung der Vereinigung der Pflanzenzüchter und Saatgutkaufleute Österreichs 2009: 49 – 51.

Strategies to avoid inbreeding depression in population cultivars of maize

Mareile Stever[1], Florian Burkard[2], Monika Messmer[3], Heiko C. Becker[1]

[1]Department of Crop Sciences, Georg-August-Universität Göttingen, Von-Siebold-Str. 8, 37075 Göttingen, Germany, mstever@uni-goettingen.de, [2] Getreidezüchtung Peter Kunz (GZPK), Hof Breitlen 5, 8634 Hombrechtikon, Switzerland, [3]Forschungsinstitut für biologischen Landbau (FiBL), Ackerstrasse 113, 5070 Frick, Switzerland

Introduction

In organic agriculture the use of hybrid cultivars is subject of controversial discussion, however in several crops nearly or only hybrids are on the market today. In maize (*Zea mays*), even in breeding programs specifically for organic farming, hybrid cultivars are developed. "Getreidezüchtung Peter Kunz" (GZPK) in Switzerland is one of the few breeding initiatives developing open-pollinated population cultivars in maize (Müllner & Kunz 2013). The progenitors for this breeding program are modern high yielding hybrid cultivars, as the agronomic performance of old landraces is not competitive any more. In old landraces self-pollination is largely prevented by protandry, the male flower is earlier than the female flower. In modern hybrid cultivars developed from inbred lines, however, male and female flowering is often synchronously. Therefore, the rate of self-pollination might be increased leading to inbreeding depression and reduced yield. In cooperation with GZPK two approaches are investigated to avoid or reduce inbreeding depression in maize populations derived from modern hybrids.

The first approach is to test the effect of selection for a large ASI. In 2011 the ASI of 54 modern hybrid cultivars was studied. Averaged across two locations (Hombrechtikon, CH, and Göttingen, D) the ASI was 0.4 days, and we often found protogynie. Eight hybrids with a short ASI (on average 0.1 day) and another eight hybrids with a comparatively large ASI (on average 1.8 days) were selected to form two open-pollinated populations that were grown in 2012 in isolation to other maize. They were grown each in two variants: detasseled (to prevent self-pollination) and open-pollinated. The progenies of the different variants are grown in 2013 for yield tests. The hypothesis is that the inbreeding depression is smaller in populations with large ASI. The rate of self-pollination will be detected with marker analysis, and additionally the yield for each of the two variants for the population with the short and the one with the long ASI will be compared.

The second approach is to develop population cultivars from hybrids with small inbreeding depression after selfing that means to select hybrids with a high S1 performance. For that reason we tested 20 hybrids and their selfed progenies (S1) in 2012. We found variation for yield between the hybrids and also between their S1s. The yield reduction in % was larger for the highest yielding genotypes. Thus, it is necessary to consider also the absolute S1 performance when choosing hybrids to form a population.

We thank KWS SAAT AG for conducting field trials. This research is funded by the Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz.

Müllner, A. & Kunz, P. *Methodenentwicklung zum Aufbau von nachbaufähigen Sorten am Beispiel Mais*. Available at http://www.getreidezuechtung.ch/index.php?article_id=430 [date of consultation: 23/07/13].

Organic vegetable breeding at Sativa Rheinau

Noémi Uehlinger, Friedemann Ebner, Amadeus Zschunke

Sativa Rheinau, Klosterplatz, 8462 Rheinau, Switzerland; n.uehlinger@sativa-rheinau.ch

Organic growers need varieties that are bred for the specific needs of organic farming systems. Under organic conditions, nutrient release from organic manure cannot be steered as exactly as with mineral fertilizers. By renouncing to synthetic-chemical pesticides and herbicides, organic growers distance themselves from the conventional control approach. They aim at supporting the whole agro-ecological system by stimulating self-regulation processes. In this context, plant varieties are needed that combine a general robustness, a high resilience and a good yield stability.

At Sativa Rheinau we breed for open-pollinated varieties (OPV) with an intentionally broad genetic background. Through their broad genetic basis, OPV are best to cope with the wide range of environments and cultural practices found in organic systems. They also offer a basis for further selection and adaptation to a specific site. In our breeding programs, all selection steps are done under organic field conditions. Field selection allows us to assess the overall robustness and reliability of plants or breeding lines. The selected genotypes are those that can rely on well-developed root system and efficient nutrient uptake.

Our main breeding goal is always a high marketable yield under organic conditions. Further, a good robustness towards diseases and abiotic stresses is always taken into account. Finally, we like to select our lines for taste, as it is an important aspect of consumers' preference for organic products.

Selection for frost tolerance in soybean

David Gloger, Bernd Horneburg

Section Genetic Resources and Organic Breeding, Division of Plant Breeding, Georg-August-Universität Göttingen, Von-Siebold-Str. 8, 37075 Göttingen, Germany; bhorneb@gwdg.de

Introduction

Within the project "Expansion of soybean cultivation in Germany through adaptation by breeding as well as optimization of crop production and processing technology" the selection for cold tolerance is explored. Here we concentrate on frost tolerance in early development.

Material and methods

Per 4 F_3- and 3 F_4-families 16 progenies, an unselected bulk and the checks Funke and Merlin were sown in single rows with 22 plants at 12/04/2012. After minimum temperatures of –2.2°C frost damage was scored. In 2013 per family 1 progeny with low frost damage, 1 with high frost damage, the unselected bulk, and the 2 checks were sown in a split plot design (whole plot=family) with 2 replicates in 4m² plots at 17/04/2013. After minimum temperatures of –2.1°C frost damage was scored. The experimental site were organic fields at Deppoldshausen near Göttingen, 300 m above sea level.

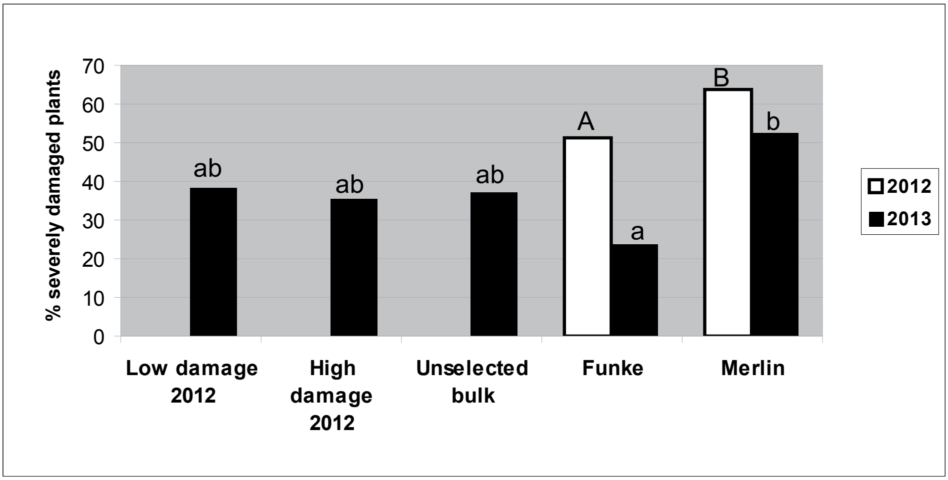


Fig. 1: Percentage of severely damaged plants in selections and check varieties. Different letters indicate differences significant at p=0.05 in Tukey's test

Results and discussion

No significant difference was observed between the selection for low damage, high damage, and unselected bulk (Fig. 1). Significant differences between the check varieties in both years, however, indicate genotypic variation.

As a preliminary result we suggest i) to improve the selection of parents and ii) to increase the number of replications and/or locations to deal with the large experimental error of the trait frost damage. The limited number of seeds per plant is a severe restriction.

Acknowledgment

The initial populations derived from breeding programs of A. Schori / Agroscope Changins-Wädenswil and V. Hahn / University of Hohenheim. Funds were granted by BÖLN.

Weed tolerance in soybean: A selection system

Sabrina Seiffert, Bernd Horneburg

Section Genetic Resources and Organic Breeding, Division of Plant Breeding, Georg-August-Universität Göttingen, Von-Siebold-Str. 8, 37075 Göttingen, Germany; bhorneb@gwdg.de

Introduction

Weed infestation is a major constraint to soybean production world-wide and in organic farming in particular (Vollmann et al., 2010). To support breeding for weed tolerance a selection system using crop plants as 'artificial weeds' was developed in Central Germany.

Materials and methods

In a split plot design 6 soybean genotypes (whole plots) where grown with 2 (2012) or 4 (2013) replications with 3 treatments: Weed free control, weed I = winter rye + spring wheat + *Setaria italica*, and weed II = winter oilseed rape + *Phacelia* + buckwheat. Plot size 5m², rows spaced 30cm apart, 70 seeds per m² were sown of both soybean and weeds (same number per species) at 2/05/2012 and 2/05/2013. Experimental site: Reinshof organic fields.

Results and discussion

Competition was induced in early soybean growth stages by the winter crops rye and oil seed rape, in mid season by spring wheat, *Phacelia,* and buckwheat. The latter two can compete until late in the season. *S. italica* was of no importance.

2012 seed yield was reduced to 82 or 48%, respectively (Fig. 1) by weed competition. Already in early developmental stages soybean dry matter was reduced. Generally, early development was much slower in 2013. Light interception of the soybean/weed canopy at 9/07/2013 was 89.2%, 84.6%, and 94.2% for weed free, weed I, and weed II, respectively. For all traits differences between treatments were significant at p=0.01.

In conclusion a system has been created to induce weed stress of different levels in small plots throughout the growing season.

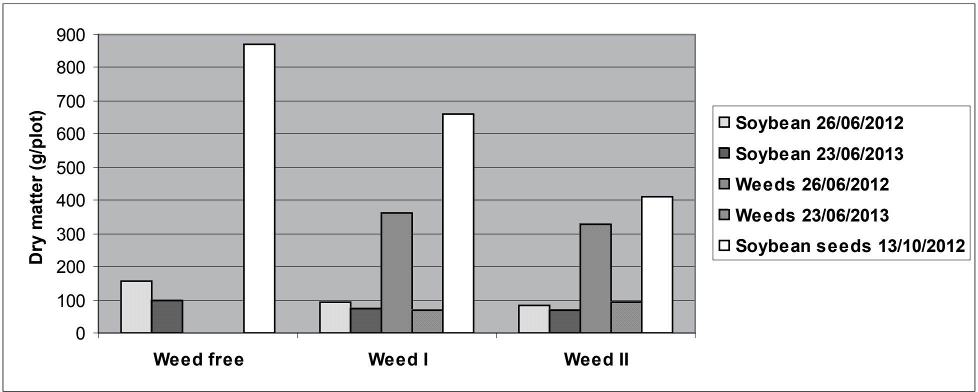


Fig. 1: Dry matter of soybean and 'artificial weeds' 2012 and 2013
Subplots early development 1m²; subplots soybean seeds 4m²

References

Vollmann, J., Wagentristl, H. & Hartl, W. (2010) The effects of simulated weed pressure on early maturity soybeans. Europ. J. Agronomy 32: 243–248.

Quality traits of diverse curly kale genotypes in organic management

Bernd Horneburg[1], Mira Dankowsky[2], Jürgen Herwig[1], Elke Pawelzik[2,] Inga Smit[2]

[1]Georg-August-Universität, Section Genetic Resources and Organic Breeding, Division of Plant Breeding, Von-Siebold-Str. 8, D-37075 Göttingen; bhorneb@gwdg.de, [2]Section Quality of Plant Products, Carl-Sprengel-Weg 1, D-37075 Göttingen

Introduction

Curly kale (*Brassica oleracea* var. *sabellica*) is a winter vegetable mainly used in Northern Germany and The Netherlands. In East Friesia many local genotypes have been selected for decades by devoted gardeners and farmers (Ehrentraut & Horneburg, 2003). The aim of this study was to compare the performance of these genotypes with varieties from the collection of ARCHE NOAH of Austria and commercial varieties from the German seed trade.

Material and methods

30 curly kale genotypes were organically grown in a randomized complete block design in two (2010) or four (2011) replications in a field trial at Reinshof experimental station near Göttingen, Germany. Ascorbic acid was determined by titration with 2.6–dichlorphenolindophenol. Glucosinolates were analysed with HPLC.

Results

The ascorbic acid content differed between years (Fig. 1). On average the commercial varieties were characterized by a low ascorbic acid content; the highest content was observed in some of the very tall East Friesian genotypes. Glucosinolates, typical aroma carriers of *Brassica* vegetables, are known to be anticarcinogenic and important in curly kale (Drewnowski & Gomez-Carneros, 2000). Progoitrin, sinigrin, glucobrassicin and glucoraphanin were the most abundant glucosinolates. FVG=Frisee Vert Grand du Nord (ARCHE NOAH) had the highest content of total glucosinolates in both years. The sensory evaluation by consumers ranked FVG best in comparison with four genotypes with a lower content of glucosinolates.

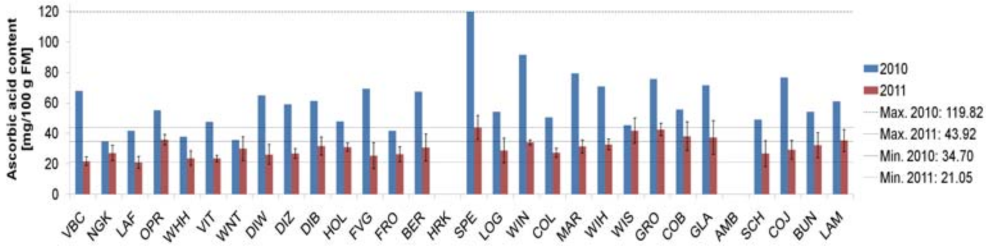


Fig. 1: Ascorbic acid content of commercial varieties (NGK=Niedriger Grüner Krauser, LAF=Lage Fijngekrulde, VIT=Vitessa, WNT=Winnetou F_1, FRO=Frostara) and genotypes selected on-farm or by an NGO. Genotypes are arranged according to plant height from VBC= 29 cm to LAM= 102 cm

References

Drewnowski, A. & Gomez-Carneros, C. (2000) Bitter taste, phytonutrients, and the consumer: a review, in: The American Journal of Clinical Nutrition 72: 1424-1435.

Ehrentraut, R. & Horneburg, B. (2003) Die Palmen Ostfrieslands unter besonderer Berücksichtigung der Kohlartigen. Schriften zu Genetischen Ressourcen 20: Biologische Vielfalt für Ernährung, Land- und Forstwirtschaft: 89-92.

Adaptation of lentil to low input conditions by natural selection on farm

Bernd Horneburg, Heiko C. Becker

Division of Plant Breeding, Department of Crop Sciences, Georg-August-Universität Göttingen, Von-Siebold-Str. 8, 37075 Göttingen, Germany; bhorneb@gwdg.de

Introduction

The use of farm saved seeds is a means to reduce external input and it also allows for evolutionary adaptation to site specific conditions. To date little is known about the mechanisms involved, their significance, and the development of overall diversity by on-farm management at multiple sites.

The experiment is carried out with lentil (*Lens culinaris* Medik.). Lentil production has almost ceased to exist in Central Europe, but lentils may still be found in gene banks and have remained a popular food.

Material and methods

Three old lentil (*Lens culinaris* Medik.) varieties were exposed to 10 generations of natural selection at three very different sites on-farm in rainfed conditions in Central and Northern Germany. Two of the selection sites were on poor or marginal soils with a frequent shortage in water supply. At one of the sites all three varieties were selected during six generations for small and large seeds, respectively.

Lentil is an autogamous crop; cross pollination is limited to 1-4% (Horneburg, 2006).

Results and Outlook

After four years of natural selection significant changes in agronomic, morphological, and phenological traits had occurred. For one variety natural selection had increased seed weight (Horneburg & Becker, 2008, Horneburg, 2003).

In the next steps the original populations, generation 5, and generation 10 from all sites shall be investigated in field trials at the selection sites. Additionally the populations will be characterized by molecular markers.

In field experients with and without drought stress the importance of water supply as a cause for natural selection shall be assessed.

Populations selected for small and large seeds, respectively will be in grown in field trials to investigate the correlation of seed size, agronomic performance, and fitness related traits.

Acknowledgment

We thank our colleagues on farm, for a number of years of cooperation. We are indebted to the German Federal Ministry of Consumer Protection, Food and Agriculture for funding the project ‘Enhanced species diversity in agriculture by means of lentil production and on-farm management’.

References

Horneburg, B. (2006) Outcrossing in lentil (*Lens culinaris* Medik.) depends on cultivar, location, and year and varies within cultivars. *Plant Breeding* 125: 638-640.

Horneburg, B. (2003) Standortspezifische Sortenentwicklung - eine Studie mit Landsorten der Linse. *Schriften zu Genetischen Ressourcen* 21. Available at http://www.genres.de/service/publikationen-informationsmaterial/schriftenreihe/

Horneburg, B. & Becker, H.C. (2008) Crop adaptation in on-farm management by natural and conscious selection. A case study with lentil. *Crop Sci* 48: 203-212.

Influence of the growing system on agronomic parameters of "wild" and cocktail tomatoes from organic outdoor production

Inga Smit[1], Catharina Kühn[1], Elke Pawelzik[1], Bernd Horneburg[2]

[1]Georg-August-Universität, Section Quality of Plant Products, Carl-Sprengel-Weg 1, D - 37075 Göttingen,[2] Section Genetic Resources and Organic Breeding, Division of Plant Breeding, Von-Siebold-Str. 8, D - 37075 Göttingen; bhorneb@gwdg.de

Introduction

Late blight caused by *Phytophthora infestans* severely restricts low input tomato production outdoors. Some selected small fruited genotypes have a high level of field resistance. Grown as staked tomatoes pruned to one shoot, however, their yield is insufficient. There is a demand for novel low input production systems like the "Göttinger System".

Material and methods

Two "wild" tomato and two cocktail tomato genotypes selected in the Organic Outdoor Tomato Project (Horneburg & Becker, 2011) were cultivated in the years 2009 and 2010 in an organic outdoor trial. In 2009 three growing systems were compared: Plants pruned to i) one shoot ii) three shoots and iii) unpruned plants in the Göttinger System. In 2010 only i) and iii) were studied. Distance between rows 2.5 m, distance between plants 0.5 m in i) and ii), 1 m in iii).

Results and discussion

While fruit weight was generally reduced in the Göttinger System, yield was increased (Fig. 1) due to a much higher number of fruits (up to >800 per plant). The reduced fruit weight in the multi-shooted system may be explained by competition for assimilates. The end of the harvest period was accompanied by increased infection with *P. infestans* and reductions in yield. Growing tomato plants in the Göttinger System tends to increase the infection with *P. infestans*. Nevertheless, little or no pruning of small fruited "wild" and cocktail tomato genotypes is a promising tool to enhance the fruit yield and reduce labour input in pruning.

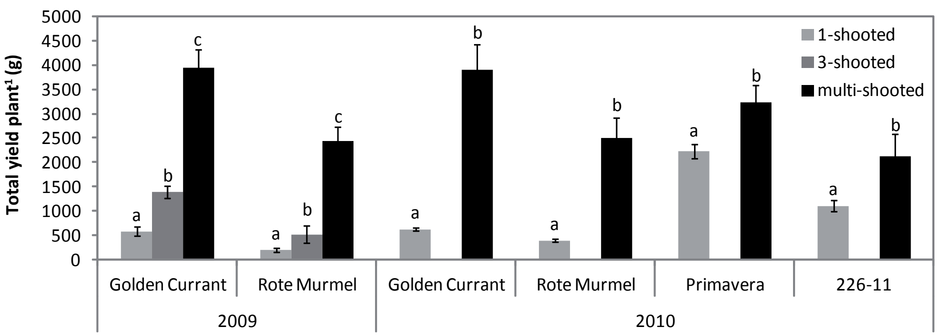


Fig. 1: Yield per plant. Data represent means and standard deviations (n = 3). Different letters indicate significant variation between growing systems within each genotype and year (ANOVA and Tukey's test; $\alpha \leq 0.05$).

References

Horneburg, B. & Becker, H. C. (2011) Selection for *Phytophthora* field resistance in the F_2 generation of organic outdoor tomatoes. Euphytica 180: 357-367.

Low input production system can improve the quality of small fruited tomatoes

Bernd Horneburg[1], *Catharina Kühn*[2], *Kerstin Dreischmeier*[2], *Elke Pawelzik*[2], *Inga Smit*[2]

[1] *Georg-August-Universität, Section Genetic Resources and Organic Breeding, Division of Plant Breeding, Von-Siebold-Str. 8, D-37075 Göttingen; bhorneb@gwdg.de* [2] *Section Quality of Plant Products, Carl-Sprengel-Weg 1, D-37075 Göttingen*

Introduction

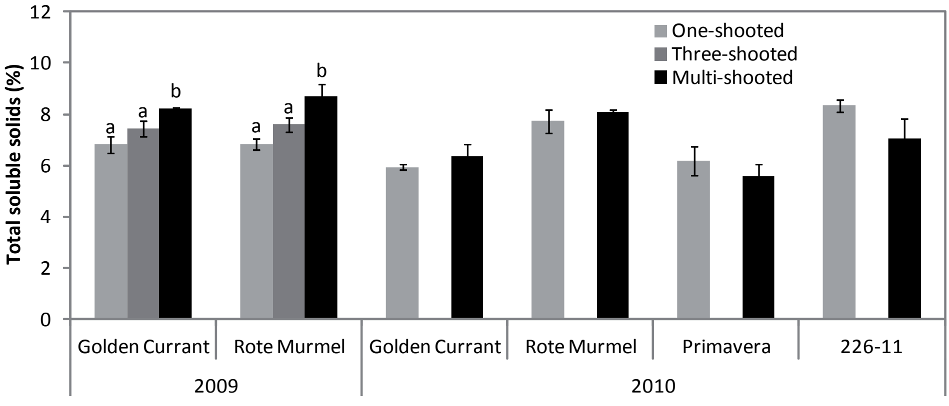
Among fresh vegetables tomatoes reach the highest per capita consumption in Germany in the last decade with an increasing market share of cocktail tomatoes (Niehues 2005). Late blight caused by *Phytophthora infestans* severely restricts low input tomato production outdoors (Foolad et al., 2008). Some selected small fruited genotypes have a high level of field resistance. Grown as staked tomatoes pruned to one shoot, however, their yield is insufficient. Thus, there is a demand for novel production systems.

Material and methods

Two "wild" tomato and two cocktail tomato genotypes selected in the Organic Outdoor Tomato Project (Horneburg & Becker, 2011) were cultivated in the years 2009 and 2010 in an organic outdoor trial. In 2009 three growing systems were compared: Plants pruned to i) one shoot ii) three shoots and iii) unpruned plants in the "Göttinger System". In 2010 only i) and iii) were studied. Distance between rows 2.5 m, distance between plants 0.5 m in i) and ii), 1 m in iii).

Results and discussion

In 2009 fruits of Rote Murmel from the unpruned plants were sweeter and less bitter, resulting in a better overall sensory rating. In tendency similar observations were made in 2010. Results of the sensory evaluation were supported by measurements of total soluble solids (Fig. 1) and titratable acids in 2009. One explanation might be a higher leaf to fruit ratio of the multi-shooted plants gaining more assimilates. Growing "wild" tomatoes with little or no pruning seems to be a promising tool for enhancing the sensory quality.



References

Horneburg, B. & Becker, H. C. (2011) Selection for *Phytophthora* field resistance in the F_2 generation of organic outdoor tomatoes. Euphytica 180: 357-367.

Foolad, M.R., Merk, H.L. & Ashrafi, H. (2008) Genetics, Genomics and Breeding of Late Blight and Early Blight Resistance in Tomato. Critical Reviews in Plant Sci, 27: 75–107.

Niehues, R. (2005) Die kleine Marktstudie: Tomaten. Gemüse 9/2005: 48-50.

P 52

Breeding for micronutrients improvements in rice (*Oryza sativa* L) for better human health

Muhammad Ashfaq[1], Muhammad Saleem Haider[1], Abdus Salam Khan[2] Muhammad Ali[1] and Farooq Ahmad[1]

[1]Institute of Agricultural Sciences, University of the Punjab, Lahore, Pakistan, ashfaq.iags@ pu.edu.pk
[2]Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan

A good number of genotypes (local + exotic) were used for the improvement of micronutrients value in Basmati rice germplasm through conventional breeding programme for better human health. Analysis of variance and correlation of different morphological traits these genotypes were studied. All the genotypes showed significant variations. On the other hand, positive and negative significant associations were observed for different morphological traits of rice genotypes i.e. seed length showed positive association with seed thickness, length width ratio and 1000 grain weight ($r= 0.2644^{**}$, $r= 0.4072^{**}$, $r= 0.3691^{**}$). Seed width showed positive association with seed thickness, 1000 grain weight and seed thickness showed positive association with 1000 grain weight ($r= 0.5059^{**}$, $r= 0.3131^{**}$, $r= 0.2929^{**}$). The variety KBNT lpa1-1 having high micronutrient value was used for the screening of other genetic material and for the production of new rice lines through recombination with high number of micronutrient value and good yield potential. For this purpose the screening was done through PCR analysis by using different number of SSR primers through CTAB method. The overall objective of the study was to screen out the diverse germplasm lines with high micronutrients value for further production of new desirable rice lines through conventional breeding programme. A good number of new rice lines (IR-64, Basmati-385 and Basmati-370) were screened out by studying the various phenotypic and genotypic traits for the later generations study and selection to increase the homozygosity of each rice line. The mean number of alleles per locus was 3.66, and the average number of polymorphism information content (PIC) values (0.561) was also observed that showed genetic variation among all genotypes. It is concluded that, all the genotypes showed almost significant genetic variability on the basis of their seed morphological traits

Excursion Experimental Station Wiebrechtshausen

Demonstration of breeding and research activities

Silage- and grain maize trials under organic conditions in Wiebrechtshausen 2013

144 x 302 m = 4,35 ha

Breeding Trials: 6 10 x 10 lattices with 2 replications

99600		99581	100200		100181
99561		99580	100161		100180
99560		99541	100160		100141
99521		99540	100121		100140
99520	148	99501	100120	151	100101
99481		99500	100081		100100
99480	Breeding	99461	100080	Breeding	100061
99441		99460	100041		100060
99440		99421	100040		100021
99401		99420	100001		100020
99400		99381	100000		99981
99361		99380	99961		99980
99360		99341	99960		99941
99321		99340	99921		99940
99320	147	99301	99920	150	99901
99281		99300	99881		99900
99280	Breeding	99261	99880	Breeding	99861
99241		99260	99841		99860
99240		99221	99840		99821
99201		99220	99801		99820
99200		99181	99800		99781
99161		99180	99761		99780
99160		99141	99760		99741
99121		99140	99721		99740
99120	146	99101	99720	149	99701
99081		99100	99681		99700
99080	Breeding	99061	99680	Breeding	99661
99041		99060	99641		99660
99040		99021	99640		99621
99001		99020	99601		99620

24790	144	Synthetics	24771
24751			24770
24740	143	Inbreeding depression of open pollinated hybrids	24721
24701			24720
24640	142	Hybrid performance	24621
24601			24620

24400		24391	24600		24591
24381		24390	24581		24590
24380		24371	24580		24571
24361		24370	24561		24570
24360		24351	24560		24551
24341		24350	24541		24550
24340		24331	24540		24531
24321		24330	24521		24530
24320		24311	24520		24511
24301	KM 140	24310	24501	KM 141	24510
24300		24291	24500		24491
24281	Test	24290	24481	Test	24490
24280	without	24271	24480	with	24471
24261	artificial	24270	24461	artificial	24470
24260	weed	24251	24460	weed	24451
24241		24250	24441		24450
24240		24231	24440		24431
24221		24230	24421		24430
24220		24211	24420		24411
24201		24210	24401		24410

24920		24915
24909		24914
24908		24903
24897		24902
24896		24891
24885		24890
24884		24879
24873		24878
24872		24867
24861	KM 145	24866
24860		24855
24849	Test of	24854
24848	undersown	24843
24837	crops	24842
24836		24831
24825		24830
24824		24819
24813		24818
24812		24807
24801		24806

831720	Intercropping Maize/Climbing Beans	831641
831561	Breeding Methods for Org. Farming	831640
831560	Dual use varieties and Intercropping	831481
831401	Maize- and Sunflower Varieties	831480

Demonstration 1

831880		831861
831841		831860
	Intercropping	
831840		831821
	Maize/Climbing Beans	
831801		831820

Demonstration 2

831980		831961
	without arificial weed	
831941		831960
	Response of selection	
831940		831921
	with artificial weed	
831901		831920

Demonstration 3

832144		832109
832073		832108
	Test of undersown crops	
832072		832037
832001		832036

Demonstration 4

Breeding methods for the development of maize varieties for organic farming

Walter Schmidt, KWS SAAT AG

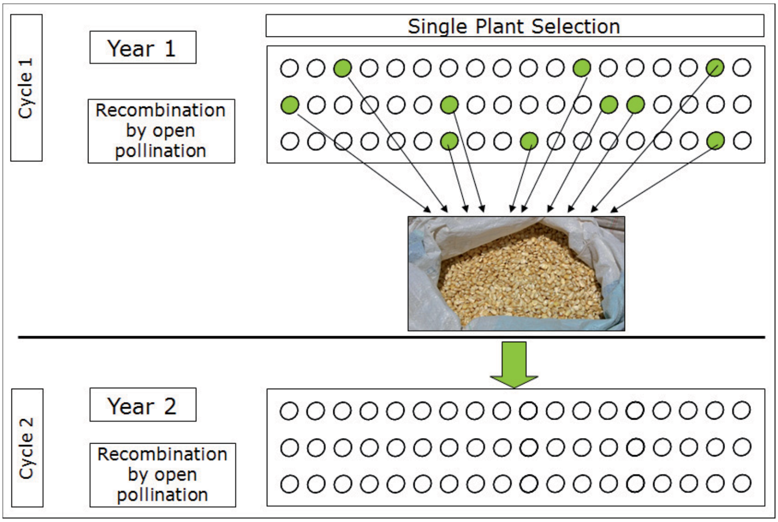


Fig. 1: Mass Selection

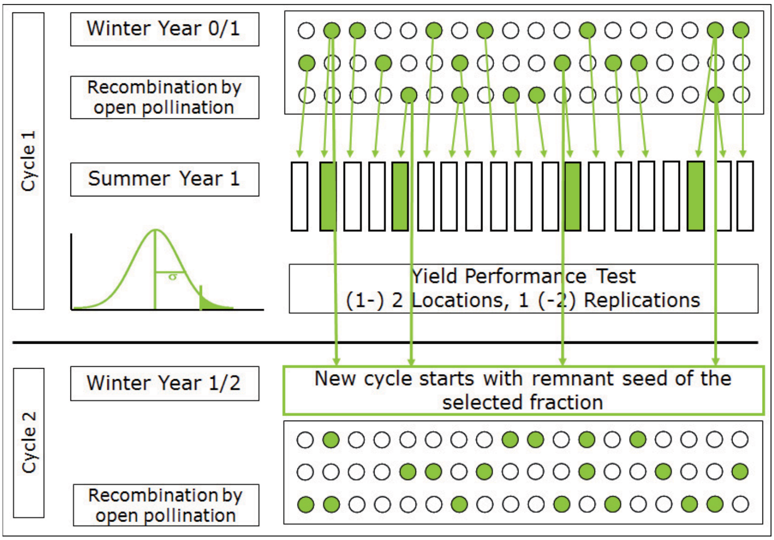


Fig. 2: Half Sib Selection (with remnant seed)

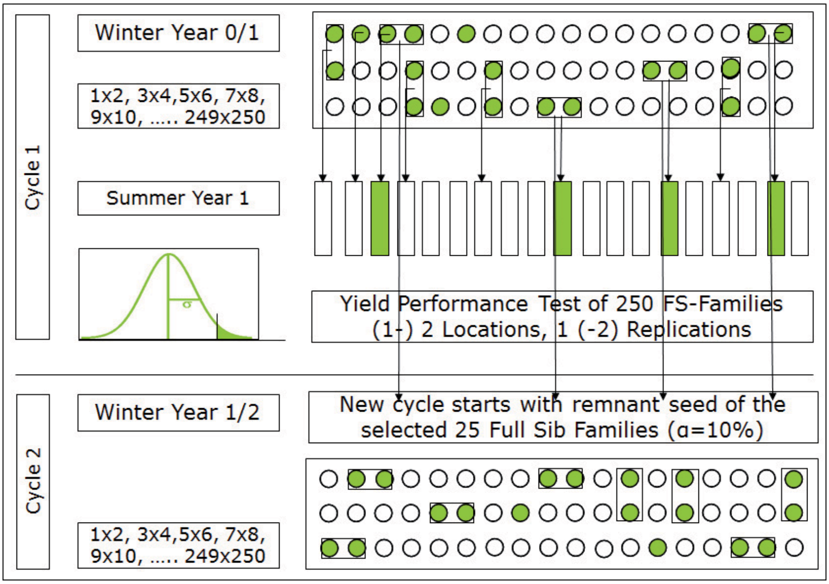


Fig. 3: Full Sib Selection (with remnant seed)

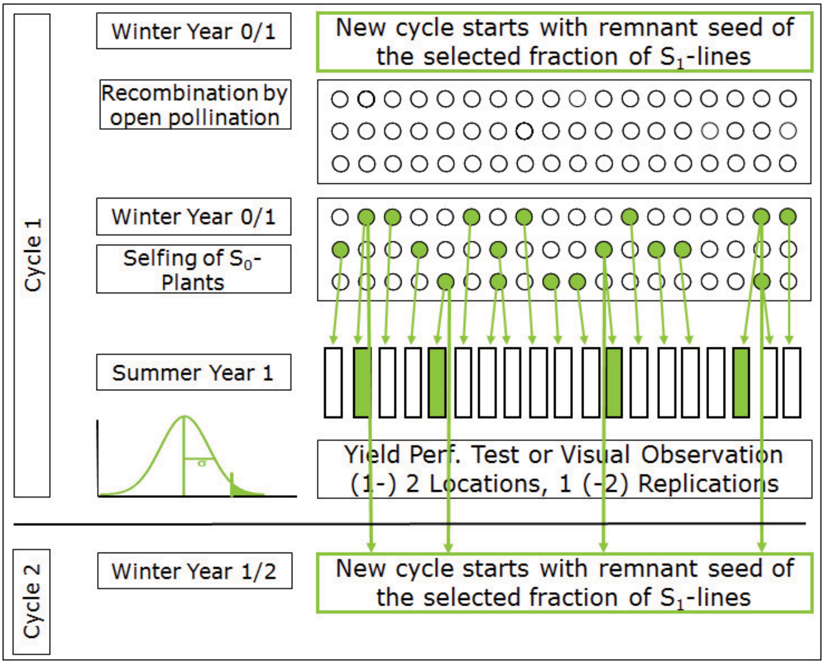


Fig. 4: S1-*per-se* Selection (with 2 winter generations)

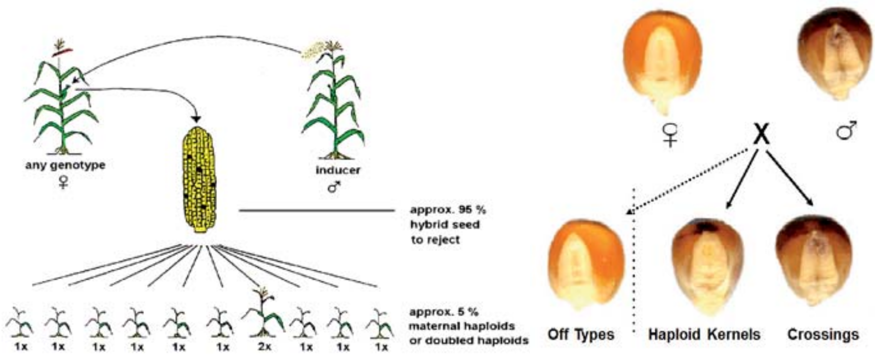


Fig. 5: Recurrent Haploid Selection: Production and selection of haploid kernels (Source: Geiger et al. 2001)

Fig. 6: Recurrent Haploid Selection: Selection of haploid plants in 3 isolation plots (IPs) at 3 sites under conventional or organic conditions in 2012. The male parent in the IPs is the population from which the haploid plants were developed.

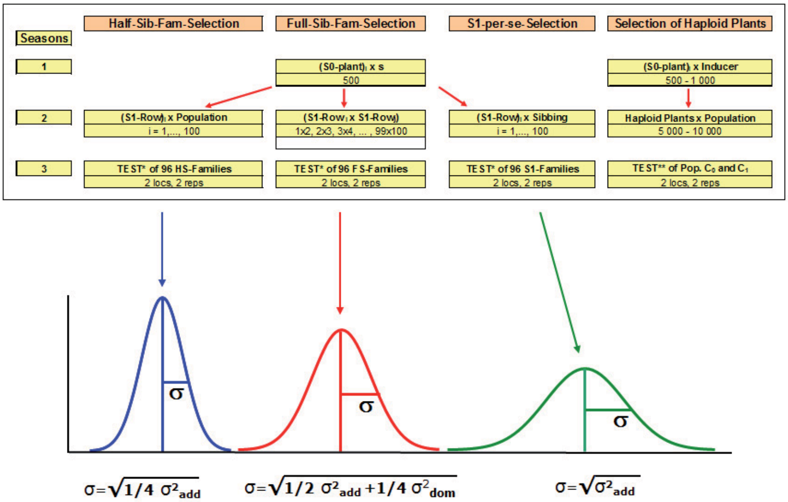


Fig. 7: Comparison of 4 breeding methods for the development of open pollinated varieties in the KWS Capacity Development Project Peru.

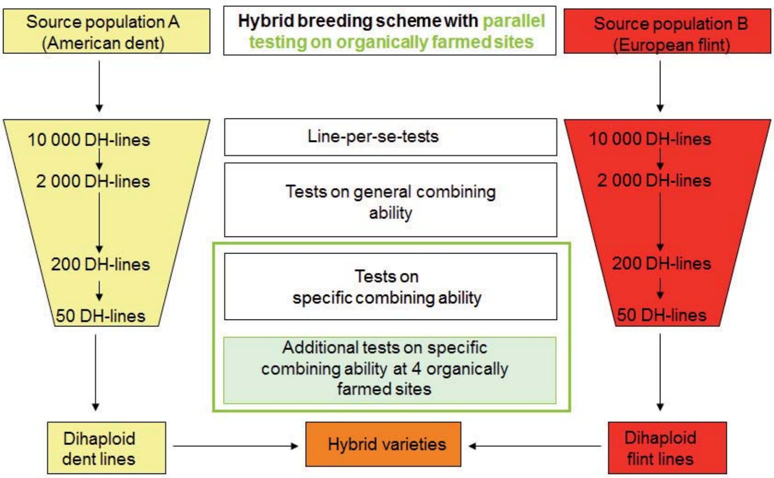


Fig. 8: Combination of conventional and organic varietal development in the German maize breeding program of KWS

Improving energy maize with specific adaptation to intercropping with climbing beans

Christopher Hoppe[1], *Walter Schmidt*[2], *Heiko C. Becker*[1]

[1]*Department of Crop Sciences, Georg-August-Universität Göttingen, Von-Siebold-Str. 8, 37075 Göttingen Germany, choppe2@uni-goettingen.de;*
[2]*KWS SAAT AG, Grimsehlstraße 31, 37574 Einbeck ,Germany*

Maize (*Zea mays*) is today the most important substrate for biogas production in Germany. The increasing acreage of maize in recent years led to concerns as to the loss of biodiversity and consequently to political restrictions. One approach to increase biodiversity is the intercropping of maize with climbing beans (*Phaseolus vulgaris*). This mixed cropping system can reach yields of nearly 100 % compared to a sole maize cropping system, although neither maize nor beans have been bred for this system.

In a research project we tested 200 maize genotypes in 2012 in a sole maize system and in intercropping with the bean cv. "Neckarkönigin". (see abstract P 38 in this Conference Booklet).

The first year results clearly showed, that a maize/climbing bean intercropping system not only requires maize genotypes with a specific adaptation but also climbing bean cultivars suitable for intercropping. Therefore we are planning to screen a genetically very diverse set of climbing bean cultivars for their suitability for intercropping with maize.

In the field demonstration the huge variation within climbing beans is shown. In 2-row plots a standard maize genotype is grown together with the climbing bean cultivars listed in the table.

Table: Climbing bean cultivars shown in demonstration plots.

Bean cv.	TKW [g]
Anellino Verde	305
Solista	891
Weinländerin	240
Klosterfrauen	490
Berner Landfrauen	331
Neckargold	309
Grünes Posthörnli	442
Coco Sophie	527
Mais/Tarbais	670
Borlotto Lamon	828
Borlotto Stregonta	656
Borlotto Lingua die Fuoco	672
Blauhilde	354
Meraviglia de venezia grano nero	498
Blue Lake	206
Cornetto Largo verde	473
Alaric	684

The project is financially supported by German Agency for Renewable Resources (FNR)

Development of maize hybrids with high weed tolerance for organic farming systems

Mareile Stever [1], Walter Schmidt [2], Henriette Burger [2], Heiko C. Becker [1]
[1]Department of Crop Sciences, Georg-August-Universität Göttingen, Von-Siebold-Str. 8, 37075 Göttingen, Germany (mstever@uni-goettingen.de); [2]KWS SAAT AG, Grimsehlstraße 31, 37574 Einbeck, Germany

In organic farming maize *(Zea mays)* is not as important as in conventional farming though it would be of great interest for animal nutrition or as cash crop. But maize is not meeting the high demands of organic farming to its germination, early vigour, tolerance to nitrogen deficiency situations, and, most importantly, tolerance against weeds. The purpose of this project is to develop maize hybrids with high weed tolerance and to compare selections with and without weed pressure. To bypass the problem that the spontaneous weed pressure largely varies within one field an artificial weed was intersown (see poster P 43 in this Conference Booklet).

In 2013 the experiments are performed as follows:
- 2 locations: Wiebrechtshausen und Göttingen
- 2 replications
- 1 variant without weed and 1 variant with 'artificial weed', a mixture of:
    - buckwheat (*Fagopyrum esculentum*)
    - rye (*Secale cereale*)
    - chicory (*Cichorium intybus*)
- In each variant two factorials between 7 Flint and 7 Dent lines are tested. The lines are selected over two years from originally 100 Flint and 100 Dent lines, from which testcrosses were grown in 2011 in both variants. Twenty-two Flint and 22 Dent lines were selected from each of the variants and tested as testcrosses in 2012 only in the respective variant. From these 7 Flint and Dent lines each were selected and crossed in a factorial.
- Maize was sown at May 6th, 2013 in Wiebrechtshausen
- 'Artificial weed' was sown at June 19th, 2013
- Measured traits are early vigour, weed score, SPAD (Minolta SPAD 502), plant height, dry matter content of the grain and grain yield

Field plan of the demonstration plots

10 genotypes selected *without* artificial weed grown *without* artificial weed
10 genotypes selected *with* artificial weed grown *without* artificial weed
10 genotypes selected *without* artificial weed grown *with* artificial weed
10 genotypes selected *with* artificial weed grown *with* artificial weed

This research project is funded by Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz.

Organic maize farming: interseeded cover crops for weed suppression

Rüdiger Jung, Rolf Rauber

Georg-August-Universität Göttingen, Department for Crop Sciences, Section Agronomy, Von-Siebold-Str. 8, D-37075 Göttingen, rjung@uni-goettingen.de, rrauber@uni-goettingen.de

Late season weeds are often recognized as threat for the main crop yield in organic maize farming. Therefore, interseeded cover crops could bear good prospects to suppress weeds in the mid and late growing season of maize. We tested several interseeded cover crops (sole or mixtures) in maize trials to evaluate their potential.

Locations: A) Reinshof near Göttingen (51°30'N, 9°56'E), silty clay loam, average annual precipitation: 645 mm. B) Wiebrechtshausen near Northeim (51°44'N, 10°01'E), silt loam, average annual precipitation: 680 mm.

Maize cultivars were established in the early days of May. Cover crops were sown four weeks later.

Table 1: Interseeded cover crops used in field trials.

Abbr.	Cover crops common names	Seeding rate kg ha^{-1}	Occurrence in regular field trials
R	winter rye (cv. Vitallo)	183	2011, 2012
W	Italian ryegrass (cv. Tigris)	30	2011, 2012, 2013
K	subterranean clover (cv. Dalkeith)	58	2011, 2012, 2013
P	chicory (cv. Grasslands Puna)	13	2011, 2012, 2013
RP	winter rye + chicory	92 + 7	2011, 2012
WP	Italian ryegrass + chicory	15 + 7	2011, 2012, 2013
KP	subterranean clover + chicory	29 + 7	2011, 2012, 2013
RPB	winter rye + chicory + buckwheat	62 + 4 +38	2011, 2012, 2013
C	squash (cv. Rouge vif d'Etampes)	28	2013
CS	squash + common bean (cv. Neckarkönigin) *	14 + 66	2013
OU	control, no cover crops, no weed management	-	2011, 2012, 2013
OO	control, no cover crops, hand weeded	-	2011, 2012, 2013

* known as "Three Sisters" in Native American agriculture: maize, beans and squash

Field trial "Demo" #4:		Maize with interseeded cover crops															Wiebrechtshausen 2013
832144																	832109
KXB CS	KXB CS	KXB CS	KXB C	KXB C	KXB C	KXB OO	KXB OO	KXB OO	KXB OU	KXB OU	KXB OU	KXB RPB	KXB RPB	KXB RPB	KXB KP	KXB KP	KXB KP
832073																	832108
KXB R	KXB R	KXB R	KXB W	KXB W	KXB W	KXB K	KXB K	KXB K	KXB P	KXB P	KXB P	KXB RP	KXB RP	KXB RP	KXB WP	KXB WP	KXB WP
832072																	832037
RIC CS	RIC CS	RIC CS	RIC C	RIC C	RIC C	RIC OO	RIC OO	RIC OO	RIC OU	RIC OU	RIC OU	RIC RPB	RIC RPB	RIC RPB	RIC KP	RIC KP	RIC KP
832001																	832036
RIC R	RIC R	RIC R	RIC W	RIC W	RIC W	RIC K	RIC K	RIC K	RIC P	RIC P	RIC P	RIC RP	RIC RP	RIC RP	RIC WP	RIC WP	RIC WP

Fig. 1: Ten varieties of interseeded cover crops (R, W, K, P, RP, WP, KP, RPB, C, CS) and two control plots (OU; OO) combined with two maize cultivars (RIC: Ricardinio; KXB: KXB 2111) for public demonstration at Wiebrechtshausen.

Support: "Bundesprogramm Ökologischer Landbau und andere Formen nachhaltiger Landwirtschaft (BÖLN)", Federal Ministry of Food, Agriculture and Consumer Protection (Germany).

Excursion Experimental Station Reinshof

Georg-August-Universtität Göttingen

Section Genetic Resources and Organic Breeding

Bernd Horneburg, Barbara Wedemeyer-Kremer

Georg August Universität Göttingen, Division of Plant Breeding, Section Genetic Resources and Organic Breeding, Von-Siebold-Str. 8, 37075 Göttingen, Germany, bhorneb@gwdg.de

Organic Outdoor Tomato Project (*Lycopersicon* spec.**)**

Tomatoes are the most important vegetable both on the global scale and in Germany. In Germany tomatoes are grown in almost every market garden, but only 15% of the demand are met. Young plants are produced for home gardeners. A major factor limiting the production are problems in outdoor cropping systems. Outdoor production needs far less external input than the production in greenhouses or polytunnels. It is seriously impaired by late blight, a fungal disease caused by *Phytophthora infestans.* Since the 1980s the virulence of rapidly evolving *P. infestans* genotypes has increased and outdoor production almost ceased to exist.

- **53 breeding lines of cocktail and salad tomatoes**, standard varieties, and genetic resources are evaluated for field resistance against *P. infestans* and *Alternaria solani*, earliness, yield, and fruit quality. Additional test sites are the organic reserach farm Kleinhohenheim (University of Hohenheim), and Ballenhausen (Culinaris - Quality seed for wholesome food).
- **Root biomass and root distribution** of selected genotypes are assessed.
- **Resistance against *Alternaria solani* and *A. alternata*** are investigated together with University of Hohenheim and Max-Rubner-Institute.
- **Selection without pruning** is unsed to investigate field resistance, agronomic traits and **seed traits** in 17 progenies of a source of resistance against *P. infestans*.
- Demonstration of the **"Göttinger System**" for low input cropping.

Radicchio and sugarloaf (*Cychorium intybus* **ss***p. foliosum***)**

In cooperation with Kultursaat e.V. populations for organic horticulture and organic breeding methods are developed as alternative to hybrid varieties.

- **Inbreeding depression** in radicchio and sugarloaf will be calculated in 4 varieties by the comparison of plants deriving from selfing or larger panmictic populations, respectively.

Soybean (*Glycine max***)**

The „expansion of soybean production in Germany by breeding for adaptation and by improved cropping methods" is the aim of the present consortium.

- **Selection for cold tolerance after** emergence and during flowering is investigated with 28 selected F4 and F5 populations deriving from 7 crosses, unselected populations, and the parent genotypes. Very early sowing mid April at Reinshof (150 m AMSL) and Deppoldshausen (300 m AMSL).
- A system to select for **weed tolerance** is established. To simulate weed competition two mixtures are used as "artificial weeds" and compared to a control free of weeds: Winter oilseed rape + buckwheat + Phacelia and winter rye + summer wheat + Setaria millet. 6 soybean genotypes differing in morphological and phenological attributes are investigated for traits that increase weed tolerance.
- F5 and F6 **breeding lines for processing quality** (tofu) from Landessaatzuchtanstalt, University of Hohenheim, are tested at Reinshof and Deppoldshausen.

Sweet corn (*Zea mays)*

Agronomic performance and homogeneity of 3 population varieties and 3 hybrid varieties of extra sweet (sh2) sweet corn are assessed in cooperation with Sativa of Switzerland.

Index

List of participants

Last name	First name	Country	E-mail
Ashfaq	Muhammad	Pakistan	ashfaq.iags@pu.edu.pk
Backes	Gunter	Germany	gbackes@uni-kassel.de
Becker	Heiko	Germany	hbecker1@uni-goettingen.de
Bischofberger	Nicole	Switzerland	n.bischofberger@gzpk.ch
Bojarszczuk	Jolanta	Poland	jbojarszczuk@iung.pulawy.pl
Boller	Beat	Switzerland	beat.boller@agroscope.admin.ch
Bouchet	Anne-Sophie	France	asbouchet@rennes.inra.fr
Brandes	Haiko	Germany	haiko.brandes@agr.uni-goettingen.de
Breuer	Frank	Germany	f.breuer@kws.com
Brumlop	Sarah	Germany	brumlop@uni-kassel.de
Burger	Henriette	Germany	h.burger@kws.com
Burkard	Florian	Switzerland	f.burkard@gzpk.ch
Capouchova	Ivana	Czech Republic	capouchova@af.czu.cz
Caspersen	Siri	Sweden	siri.caspersen@slu.se
Catinaud	Philippe	France	ph.catinaud@wanadoo.fr
Chable	Veronique	France	chable@rennes.inra.fr
Chan Navarrete	Jose Rafael	Netherlands	jose.channavarrete@wur.nl
Christov	Nikolai	Bulgaria	nikolai_christov@abi.bg
Cooper	Julia	United Kingdom	julia.cooper@newcastle.ac.uk
Creissen	Henry	United Kingdom	henry.creissen@jic.ac.uk
Desclaux	Dominique	France	desclaux@supagro.inra.fr
Dresbøll	Dorte Bodin	Denmark	dbdr@life.ku.dk
Ebner	Friedemann	Switzerland	f.ebner@sativa-rheinau.ch
El Doweny	Hamdy	Egypt	prof.hamdy@hotmail.com
Fiedler	Karin	Germany	karin.fiedler@kws.com
Finckh	Maria	Germany	mfinckh@uni-kassel.de
Fontaine	Laurence	France	laurence.fontaine@itab.asso.fr
Fremann	Claire	United Kingdom	claire.fremann@kws-uk.com
Froelich	Walter	Germany	Walter.Froelich@gmx.net
Gatehouse	Angharad	United Kingdom	a.m.r.gatehouse@newcastle.ac.uk
Geiger	Hartwig	Germany	geigerhh@uni-hohenheim.de
Gemenet	Dorcus Chepkesis	Germany	chepkesis@yahoo.com
George	Tim	United Kingdom	tim.george@hutton.ac.uk
Gierschner	Andrea	Germany	andrea.gierschner@ble.de
Girling	Robbie	United Kingdom	robbie.g@organicresearchcentre.com
Glala	Ahmed	Egypt	aa.glala22@gmail.com
Gül	Muhammet Kemal	Turkey	muhammet-kemal.gul@eurochemagro.com
Haase	Thorsten	Germany	thorsten.haase@llh.hessen.de

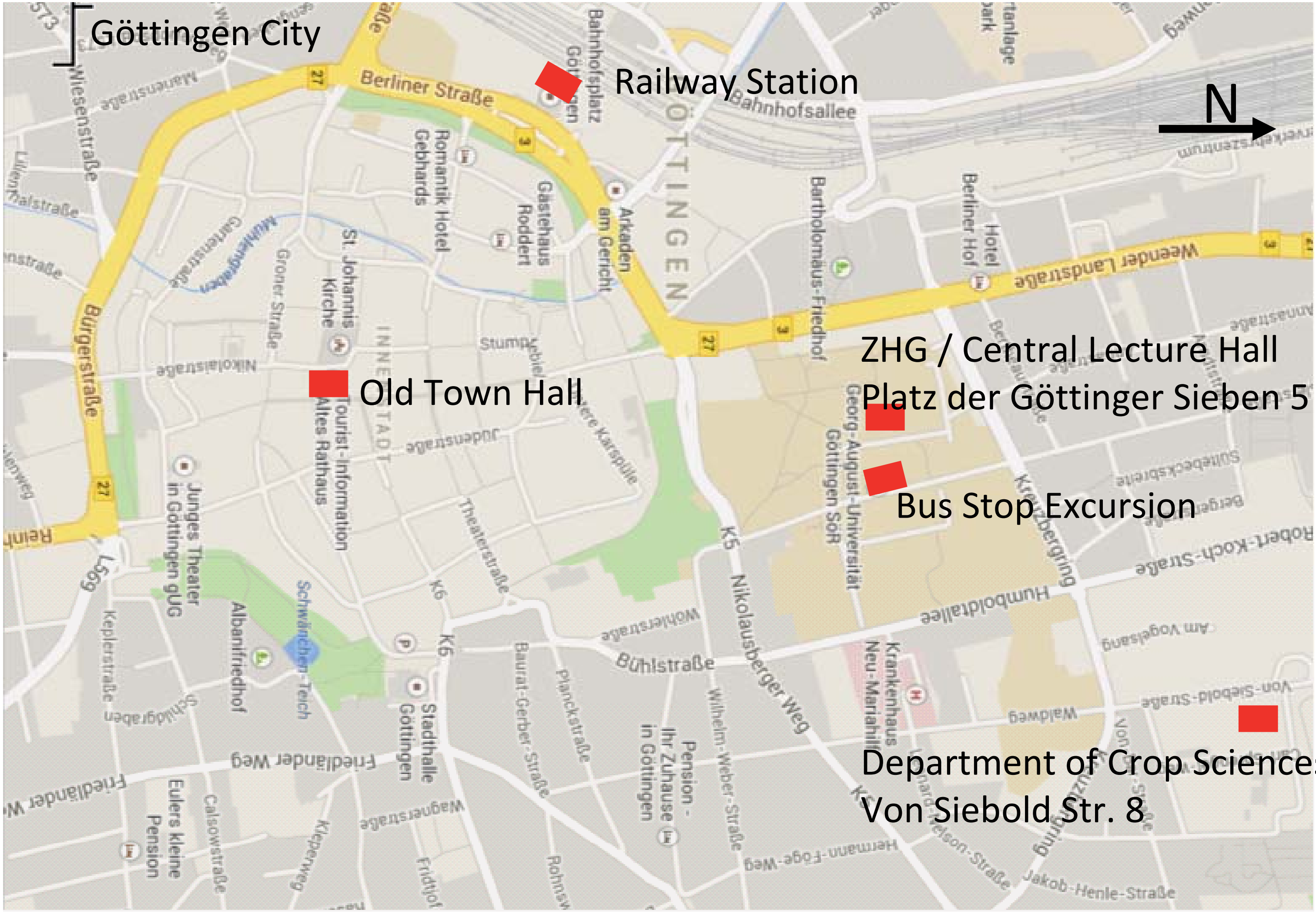
List of participants, continued

Haug	Benedikt	France	b.haug@gzpk.ch
Hecht	Vera Lisa	Germany	v.hecht@fz-juelich.de
Hoffmann	Borbala	Hungary	hoff-b@georgikon.hu
Hoffmann	Sándor	Hungary	hoffmann-s@georgikon.hu
Hoppe	Christopher	Germany	christopher.hoppe@agr.uni-goettingen.de
Horneburg	Bernd	Germany	bhorneb@uni-goettingen.de
Jajarmi	Vahid	Iran	vahid_jajarmii@yahoo.com
Janovska	Dagmar	Germany	janovska@vurv.cz
Ji	Yongran	Netherlands	yongran.ji@wur.nl
Jiang	Lixi	China	jianglx@zju.edu.cn
Jung	Rüdiger	Germany	rjung@gwdg.de
Karuniawan	Agung	Indonesia	akaruni1@unpad.ac.id
Kerbiriou	Pauline	Netherlands	pauline.kerbiriou@wur.nl
Klaedtke	Stephanie	France	klaedtke@ibla.lu
Klauck	Julia	France	chable@rennes.inra.fr
Knapp	Samuel	Switzerland	samuel.k@gmx.de
Konvalina	Petr	Czech Republic	petr.konvalina@gmail.com
Księżak	Jerzy	Poland	jerzy.ksiezak@iung.pulawy.pl
Lakew	Berhane	Ethiopia	berhanekaz@yahoo.com
Lammerts van Bueren	Edith	Netherlands	edith.lammertsvanbueren@wur.nl
Laperche	Anne	France	anne.laperche@agrocampus-ouest.fr
Le Campion	Antonin	France	alecampion@rennes.inra.fr
Legzdina	Linda	Latvia	Linda.Legzdina@priekuliselekcija.lv
Leifert	Carlo	United Kingdom	carlo.leifert@newcastle.ac.uk
Leiser	Willmar	Germany	willmar_leiser@uni-hohenheim.de
Link	Wolfgang	Germany	wlink@uni-goettingen.de
Löschenberger	Franziska	Austria	franziska.loeschenberger@saatzucht-donau.at
Lovrić	Ana	Croatia	alovric@agr.hr
Lynch	Jonathan	USA	jpl4@psu.edu
Mavindidze	Peter	Germany	mavindidzep@yahoo.com
Meinen	Catharina	Germany	catharina.meinen@agr.uni-goettingen.de
Messmer	Monika	Switzerland	monika.messmer@fibl.org
Miersch	Sebastian	Germany	smiersc@gwdg.de
Mikó	Péter	Hungary	miko.peter@agrar.mta.hu
Mitterbauer	Esther	Germany	esther.mitterbauer@ti.bund.de
Monostori	István	Hungary	monostori.istvan@agrar.mta.hu
Mühlhausen	Ellen	Germany	ellen.muehlhausen@kws.com
Müller	Karl-Josef	Germany	k-j.mueller@darzau.de
Müllner	Almuth Elise	Austria	almuth-elise.muellner@boku.ac.at
Nuijten	Edwin	Netherlands	e.nuijten@louisbolk.nl
Ospina	Cesar	Netherlands	cesarandres.ospinanieto@wur.nl

List of participants, continued

Parra-Londono	Sebastian	Germany	sebastian.parra-londono@uni-rostock.de
Pedersen	Tove	Denmark	tmp@vfl.dk
Pestsova	Elena	Germany	elena.pestsova@uni-duesseldorf.de
Pregitzer	Anjana	Germany	anjana.pregitzer@dottenfelderhof.de
Presterl	Thomas	Germany	thomas.presterl@kws.com
Ramsay	Luke	United Kingdom	Luke.Ramsay@Hutton.ac.uk
Rey	Frederic	France	frederic.rey@itab.asso.fr
Reynoird	Jean-Paul	France	jean-paul.reynoird@lasalle-beauvais.fr
Röbbelen	Gerhard	Germany	gc.roebbelen@t-online.de
Rolland	Bernard	France	bernard.rolland@rennes.inra.fr
Šarčević	Hrvoje	Croatia	hsarcevic@agr.hr
Schierholt	Antje	Germany	aschier@agr.uni-goettingen.de
Schmidt	Walter	Germany	walter.schmidt@kws.com
Schmolke	Michael	Germany	michael.schmolke@bayer.com
Schulte auf‘m Erley	Gunda	Germany	schulteaufmerley@plantnutrition.uni-kiel.de
So	Hwat-Bing	Australia	h.so@griffith.edu.au
Stahl	Andreas	Germany	andreas.stahl@agrar.uni-giessen.de
Staniak	Mariola	Poland	mstaniak@iung.pulawy.pl
Stever	Mareile	Germany	mareile.stever@agr.uni-goettingen.de
Swain	Eleanor	United Kingdom	eleanor.swain@ncl.ac.uk
Thomas	Bill	United Kingdom	bill.thomas@hutton.ac.uk
Thorup-Kristensen	Kristian	Denmark	ktk@life.ku.dk
Uehlinger	Noémi	Switzerland	n.uehlinger@sativa-rheinau.ch
Vandenberg	Albert	Canada	bert.vandenberg@usask.ca
von Witzke-Ehbrecht	Sabine	Germany	switzke@uni-goettingen.de
Vossen	Maarten	Netherlands	m.vossen@agrico.nl
Weissinger	Helene	Austria	helene.weissinger@boku.ac.at
Welz	Therese	Germany	therese.welz@kws.com
Werner	Peter	United Kingdom	peter.werner@kws.com
Wever	Christian	Germany	christian@wever.net
Wu	Jian	China	wujian@caas.cn
Zhao	Bingqiang	China	bqzhao@caas.ac.cn

the long side of the map shows a distance measuring about 2300 m in reality



ACKNOWLEDGEMENTS

This conference was financially supported by

- Deutsche Forschungsgemeinschaft (DFG)
- Niedersächsisches Ministerium für Wissenschaft und Kultur
- EUCARPIA

We gratefully acknowledge funding from the European Community under the Seventh Framework Programme for Research, Technological Development and Demonstration Activities, for the Integrated Project NUE-CROPS FP7-CP-IP 222645.

We thank the following companies for generous support:

Deutsche Saatveredelung AG, Lippstadt, Germany

GenXPro GmbH, Frankfurt, Germany

KWS Saat AG, Einbeck, Germany

Limagrain, Edemissen, Germany

Naturkost Elkershausen, Göttingen, Germany

Norddeutsche Pflanzenzucht Hans-Georg Lembke KG,

Hohenlieth, Germany

Strube Research, Söllingen, Germany

EUCARPIA

NUE-CROPS

GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN

DFG

KWS

Niedersächsisches Ministerium
für Wissenschaft und Kultur

struberesearch

DSV

Limagrain
Deutschland

GenXPro
genes never seen before

NPZ
LEMBKE®

Naturkost
Elkershausen