

International Conference on Research on Food
Security, Natural Resource Management and
Rural Development



Tropentag

2019

**Filling gaps and removing
traps for sustainable resources
management**

Book of abstracts

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GEORG-AUGUST-UNIVERSITÄT
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Tropentag 2019

International Conference on Research on Food Security,
Natural Resource Management and Rural Development





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International Research on Food Security, Natural
Resource Management and Rural Development

Filling gaps and removing traps for sustainable resources management

Book of abstracts

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Preface

Tropentag is the largest interdisciplinary conference in Europe on research in sub-/tropical agriculture, food security, natural resource management and rural development. Taking place annually, *Tropentag* 2019 is jointly organised by the Centre for International Rural Development at the University of Kassel and the Centre of Biodiversity and Sustainable Land Use at the University of Göttingen, and takes place at the University of Kassel's main campus from 18 to 20 September 2019.

Since more than a decade *Tropentag* conferences are addressing the socio-political, economic and ecological consequences of global change phenomena for rural - and peri/urban - smallholder farmers and other groups whose livelihood depend on the use of natural resources, be it directly or indirectly. A lot of science-based yet practical solutions to site-specific problems of natural resources management and the sustainable provision of food and non-food commodities through agriculture and forestry have been provided, addressing ecological, technical, economic, social and political aspects. Yet undamped population growth, in particular in sub-Saharan Africa, continued rural-to-urban migration, such as in many Asian countries, and increasingly serious consequences of climate variability and change sometimes overrun our newly gained insights. In addition, obvious deficits or gaps, such as in quality education, equal share of responsibilities and incomes between women and men, in marketing opportunities between rural and urban farmers, between potential and actual crop yields and livestock performances, still need to be resolved in many regions of the world. Certainly, our research is limited in time and space, by financial means and available human power, and therefore it is all the more important to *a priori* identify - and avoid - common traps, such as neglect of relevant stakeholders, incomplete risk assessment, short-lived innovation testing, and fragmental systems assessment in our scientific endeavours.

“Filling gaps and removing traps for sustainable resources management” is therefore the theme of *Tropentag* 2019, and from the more than 930 contributions initially submitted 470 were found to provide very relevant aspects of this overarching theme - they are compiled in this book. A very prominent goal of *Tropentag* conference is the international - disciplinary and interdisciplinary - exchange and mutual learning. Prominent examples of successful research and development approaches towards sustainable resources management may provide us with new ideas for our own work.

The five plenary keynote contributions to this years' *Tropentag* showcase such successful strategies and concepts, be it the low-cost farmer managed natural land restoration technique for which Tony Rinaudo and Yacouba Sawadogo were awarded the Right Livelihood Award 2018, the use of voluntary sustainability standards in global food production on which Miet Maertens reflects, or the successful transfer of scientific knowledge into day-to-day policies on which Immaculate Njuthé Maina shares her insights - all of them are characterized by a holistic approach towards problem analysis and solution and provide inspiration. A special session chaired by the International Center for Agricultural Research in the Dry Areas (ICARDA), this year's CGIAR feature center, focusses on cereals and pulses for climate-smart agri-food systems, thereby also drawing attention to the aggravating problem of water scarcity in the dryer parts of the sub-/tropics.

Next to the five plenary keynote lectures the conference theme is addressed in 113 oral presentations and 362 poster contributions organised in 22 thematic sessions, and we wish to thank all participants for their scientific contributions and our colleagues of the scientific committee for reviewing all abstracts and acting as chairs for oral and poster sessions during *Tropentag* 2019. Special thanks go to Eric Tielkes for his very valuable support in compiling this book and organising the conference, and to all donors (listed on the back cover) for their financial and in kind contributions which allow us to keep conference fees at a modest level, especially for junior scientists.

We welcome you coming from the many different parts of the world to *Tropentag* 2019 in Kassel and wish you an inspiring and enriching conference with a lot of new insights, fruitful discussions and a stimulating exchange of knowledge and experiences.

On behalf of the local organising team of *Tropentag* 2019:

Eva Schlecht, Bernhard Brümmer, Simone Pfeiffer, Martin Wiehle

Kassel-Witzenhausen and Göttingen, September 2019



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Getting Your Assumptions Right

TONY RINAUDO

World Vision, Australia

Our assumptions about a problem will influence our expenditure, choice of interventions and ultimately our success. It is very important to get our assumptions correct — and to be flexible enough to adjust them as required as new information comes to light. In the early 1980's, Niger Republic was in the grip of desertification which threatened the livelihoods of it's inhabitants. The default response of both state and non-state actors was to mount massive tree replanting schemes. The approach failed socially, technically and economically and by the late 1980's, appetites for land restoration through tree planting had largely disappeared. Identifying the technical gaps and addressing the real constraints - lack of tree ownership, theft of trees and false perceptions about trees - preventing people from restoring tree cover — opened the door for a spontaneous, wildly successful social reforestation movement.

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What Is the Flavour of Good Intentions?: On Interest Divergence and Responsibility in the Cacao-Chocolate Industry

CARLA D. MARTIN

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In recent years, the cacao-chocolate industry has increasingly focused on taste - quality of flavour and the ability to discern quality - as a vehicle of market differentiation. At the same time, many of the marketing tools of specialty chocolate rely on linking good taste to social and economic goodness. The links among these elements remain blurry, are not yet clearly defined by specialty cacao or chocolate producers, and often rely on interpretations of work from related but different industries. A critical examination of the value chain indicates that the interests of those who produce chocolate frequently diverge from the interests of those who produce cacao, creating gaps and traps in work on social and environmental responsibility. The often contrary goals that impact the industry must thus be interrogated to determine the place of sustainability, and in whose best interests different players act. We must ask: what is the flavour of good intentions?

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Sustainable Food System and Job Creation under Water Scarcity

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Agri-food systems in the DryArc region (between Southern Europe, North Africa, Sub-Saharan Africa and China) face a complex combination of challenges including water scarcity, rainfall variability, increased temperatures, land degradation, desertification, high population growth and migration, widespread poverty, malnutrition and unemployment. This region is expected to be among those worst affected by climate change, where reduced agricultural productivity, increased poverty, higher dependence on food imports, and increased competition for scarce natural resources will ultimately threaten the viability of agriculture and rural livelihoods. These constraints also present opportunities to transform agri-food systems across the DryArc and scaled in the frame of the diverse range of the region's agro-ecosystems: rainfed, irrigated, agro-pastoral and desert farming. Synergies across these agro-ecosystems can be leveraged among SDGs related to nutrition security, Natural Resource Management (including soils and water) and rural development, provided the potential of the agro-biodiversity is fully utilised and properly managed. This agro-ecological transformation of fields, farms, landscape, value chains and policies will be illustrated in the cereal-based agri-food systems of the DryArc region, showing the key role that food legumes, forages, livestock and trees can play in long-term sustainable use of water and soils. The implications for water, land and labour productivity under climate change and its effects on livelihoods of the people across this region is a critical part of this discussion, informing the future direction of research for development in the context of the CGIAR's DryArc initiative.

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Filling Gaps and Removing Traps in the Use of Voluntary Sustainability Standards

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Voluntary or private sustainability standards cover a large number of tropical products and are increasingly important in global markets. The rapid spread of voluntary sustainability standards is sometimes erroneously interpreted as a sign of increased sustainability in the food system. Yet, the actual impact of such standards matters. There is a potential trap that private standards satisfy consumers' demand for more ethically and sustainably produced food products and fulfil companies' sustainable sourcing strategies while not actually contributing to improved sustainability in global food systems — thereby merely easing consumers' conscience, diverting donor money to certification programs and extracting rents from food supply chains through expensive monitoring systems. Despite substantial research efforts on this topic, important knowledge gaps remain to be filled. This presentation highlights the results from recent research on the sustainability impact of voluntary sustainability standards, with evidence from different tropical countries and sectors. The presentation includes a focus on all three components of sustainability, including social, economic and environmental issues and sustainability trade-offs. The research findings, along with earlier findings described in the literature, entail important implications towards farmers, food companies, standard-setters, policy-makers, donors and consumers on how to avoid the above-mentioned trap of widespread use of private standards without actual improvement in food system sustainability. Finally, the presentation points to some remaining research gaps that need to be addressed in order to develop a more effective system of private standards.

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Scientific Knowledge Transfer and the Science-Policy Interface: Bridging the Gaps and Overcoming the Traps

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Scientific knowledge transfer and the science-policy interface is complex and challenging. It includes contestations about the credibility and legitimacy of scientific knowledge and the strategic use of such knowledge. The cognitive distance between the scientists and science experts on one hand and the policy making institutions on the other, enhances the complexities. In addition, the willingness of scientists to engage in knowledge transfer and exchange with policy is often related to individual capacities, level of training and career trajectories, and motivations. These realities often hamper the successful knowledge transfer between the spheres of science and policy-making leading to under-exploitation of the potential for science to support decision-making. The policy-science interface is further compounded by the fact that policies often address complex, far reaching and large-scale, multi-faceted problems that present social, institutional as well as natural resources contexts. To be more effective many policy makers would need to develop scientific competences to interact more effectively with scientific experts. The policy-making process is politically-driven and involves various arms of government. Interest groups and lobbyists with different points of view are often involved. Scientists need to enhance their level of knowledge of the internal workings of policy-making processes. Once policies are enacted, there often is a lack of coordination among agencies responsible for implementing policy and this contributes to fragmentation. This presentation presents insights on the possible strategies that can fill the gaps and remove some traps in the science-policy-practice continuum for sustainable resources management. They include processes of public participation; a definition of intended outcomes; the theory of change; determination of policy anchors and enablers; as well as provisions on measurement of the transformational impact of a policy. The insights presented are drawn from recent publications on this topic as well as from practice. Inference is drawn from the Kenyan Agriculture Sector Transformation and Growth Strategy (ASTGS). This 10-year strategy supports policies that address food and nutrition security while embracing sustainable exploitation, utilisation, management and conservation of the environment and natural resources.

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Crop and cropping systems

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Difficult Time for Maize Cropping: How Can we Sustain it under Climate Extremes?

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Climate significantly affects maize (*Zea mays*) productivity. Therefore, the objective of present study was to assess growth, physiology and yield components of maize under different cropping patterns in areas prone to weather variability. The experiment was carried out in an upland maize production area of Thailand, using a split plot design with three replicates. The treatments were (i) June planted maize monocrop, (ii) July planted maize monocrop (farmers' practice) and (iii) July planted maize relay cropped with mung beans (*Vigna radiata*). Maize growth and physiological parameters (grain yield, yield components and $\delta^{13}\text{C}$ of maize grains) and soil moisture were assessed. Weather data showed that rainfall was mostly falling from June to mid-August and mean maximum temperature was 35°C. During drought periods, the maximum temperature exceeded 40°C. As a consequence, June planted maize was less affected by extreme weather conditions during sensitive periods of maize growing, while July planted maize regardless of mono or relay cropping were negatively affected. The results showed that June planted maize had a significantly better growth performance and finally a higher yield than the other two treatments tested. N uptake of June planted maize was also significantly higher compared to the other two treatments. Light transmission ratio of June planted maize was higher, reaching up to 20 %, while July planted maize treatments were above 40 %. As July planted maize treatments were highly affected by extreme climate, maize-mung bean relay cropping was higher in demanding water than maize monocrop as indicated by soil moisture depletion. Stomatal conductance of these two treatments were not significantly different during normal condition, but during extreme climate, relay cropping was still able to keep stomata open ($P \leq 0.05$). Therefore, relay cropping performed better than sole cropping when maize was planted in July. Moreover, $\delta^{13}\text{C}$ of maize grains confirmed that June planted maize had a much better water access than July planted maize. Nevertheless, July planted maize relay crop had also less water stress than the monocrop. This study indicated that maize-mung bean relay cropping can mitigate extreme weather while using a proper planting period enhances productivity of maize mono cropping.

Keywords: Climate change mitigation, mung bean, relay cropping

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Land Rental Markets in Rural Vietnam – Determinants and Welfare Effects of Renting in Crop Plots

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It is often suggested that land rental markets contribute to efficiency and equity, especially in developing countries that only recently introduced privately managed agriculture and liberalised land markets. However, our understanding of the determinants of participation in those markets remains limited, affecting the estimation of welfare effects. This paper aims at analysing the determinants and welfare effects of renting in additional plots, thereby identifying possible ways to tap into rental markets' potential. A descriptive analysis is followed by a probit regression to identify the most important determinants of the decision to rent in, while an endogenous switching regression is proposed to analyse welfare effects. The analysis is based on data from 937 households owning rice plots in rural Vietnam from 2016 and 2017, collected in the context of the DFG-funded project 283672937 (TVSEP). Households are split between those renting in additional plots and those only cultivating the plots they own (autarkic). The descriptive analysis shows that households additionally renting in achieved higher yields and net income per hectare from crop production compared to autarkic households. Moreover, their per capita home consumption of their produce was of higher value, while the ratio of home consumption to sales was smaller. These observations point to possibly significant effects of renting in additional land on productivity and food security. The results from the probit regression indicate that households with more members, smaller land endowment, and higher farming ability were more likely to rent in, while minorities were less likely to do so. The results of the selection equation in the endogenous switching regression support these findings. The results from the endogenous switching regression furthermore suggest that autarkic households achieve a lower net income per hectare from crop production than a randomly selected household, while households renting in are able to increase their profit per hectare primarily through the expansion of planted area. The results highlight the importance of households' self-selection into rental markets based on their anticipated gains. Policies should facilitate this process and increase the credibility of rental agreements by providing credit and safeguarding rental payments, which could be targeted specifically at minorities.

Keywords: Cropland rental market, determinants, endogenous switching regression, Vietnam, welfare effects

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Impact of Urbanisation on Water Bodies in Agro-Ecosystems of Bengaluru-Metropolitan City of India

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Water contamination is one of the many consequential concerns of urbanisation that need immediate attention in most cosmopolitan cities. In Bengaluru, one of the fast growing metropolitan cities in India, most of the water bodies are contaminated. However, under unabated, rapid land use changes and severe water scarcity, it is inevitable to utilise the available water for all possible uses depending on the quality of water. Thus it is critical to ascertain the extent of as well the source of contamination. Among the various causes of contamination agriculture is one of the major factors. Due to urbanisation agriculture has undergone changes in and around Bengaluru in terms of crops grown as well as cultivation practices. This study is an attempt to assess the changes in the agro-biodiversity related water quality in the agro-ecosystems along rural urban transition zones (RUT) of Bengaluru. In this study suitability of water for major utilities such as drinking, irrigation and for livestock use is assessed. Water quality is determined based on specific physical, chemical and biological indicators in ground water (n=30) as well as surface water (n=30) bodies located within one kilometer radius of agriculture lands. The mean water quality index (developed based on 22 water quality parameters) of urban surface and ground water suggest that it is not suitable for drinking but, fairly suitable for irrigation and industrial use (C3 and C4 category), while in the transition and rural area it is again not suitable for drinking purpose but suitable for irrigation and industrial use (C2 category). Piper tri-linear diagram indicate that majority of the ground and surface water samples belong to mixed Ca^{2+} - Mg^{2+} - Cl^{-} - SO_4^{4-} type, and continuous use of this water in future may lead to soil degradation and crop damage. Results indicate that water quality across the RUT of Bengaluru is deteriorating and hence there is an immediate need for improving the water resource management.

Keywords: Agro-ecosystems, drinking standards, irrigation quality, livestock quality, urbanisation, water quality index

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Grain and Tuber Yield of the African Yam Bean Intercropped with Cassava

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The African yam bean (*Sphenostylis stenocarpa* (Hoechst ex. A. Rich.) Harms.) can be considered an orphan crop, yet interest in the crop has increased recently. In DR Congo, farmers still grow the crop and keep a few varieties for grain and tuber production. The Genetic Resource Unit at the International Institute of Tropical Agriculture, Ibadan, Nigeria is keeping African yam bean (AYB) germplasm and exchanged some with DR Congo. Knowledge on AYB varietal traits and agronomic performance are lacking. A trial was conducted in 2017–2018 season on the Plateau de Bateke to assess the suitability of 4 AYB varieties for grain and tuber production and intercropping with cassava, the most common crop on the plateau. Varieties Feshi, Ngidinga, TSS10 and '209013' were seeded as sole crop and with cassava variety TME 419. Plots were $5 \times 5 \text{ m}^{-2}$, plant density was 2 AYB m^{-2} and 1 cassava m^{-2} . Soils are poor, coarse textured sand, receiving over 1200 mm rainfall, yet vegetation is grassland. Crop establishment and survival to harvest of the AYB was poor in TSS10 (0.5 plants m^{-2}) and moderate for the other varieties (0.9 plants m^{-2}). Grain yield was higher in AYB sole crops and highest in variety '209013' (268 kg ha^{-1}) followed by Feshi (191 kg ha^{-1}), TSS10 and Ngidinga produced 102 and 89 kg ha^{-1} , respectively. When intercropped grain yields were 24–60 % lower with highest losses in '209013'. Tuber yields were highest in Feshi sole crop (13.02 t ha^{-1}) followed by Feshi intercropped (10.16 t ha^{-1}). All other varieties produced significantly less (in t ha^{-1}): Ngidinga 2.85 (sole), 2.26 (intercropped); TSS10 0.09 t ha^{-1} (sole), 0.31 (intercropped) and '209013' 0.32 (sole) and 0.07 (intercropped). Feshi is the only variety with a reasonable grain yield to keep seed and a sufficient tuber yield that matches that of cassava. The cassava root yield did not respond to the presence of AYB varieties '209013', Ngidinga and TSS10 but produced significantly less (7.67 t ha^{-1} fresh roots) when intercropped with Feshi. Cassava sole crop attained 11.2 t ha^{-1} fresh roots. AYB tubers fetch a higher price than cassava roots thus AYB Feshi is an alternative to cassava.

Keywords: DR Congo, intercropping, orphan crop, *Sphenostylis stenocarpa*

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Impact of Climate on the Cassava Yield and Biomass Gap Variability in Sub-Saharan Africa - A Case Study in Nigeria

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Cassava (*Manihot esculenta* L.) production is vital to the economy of Nigeria as the country is the world's largest producer of the commodity, contributes almost 19 % of the total world production. We investigated the impact of climatic variables on yield gap variability across the three states in Nigeria using the crop model LINTUL5 embedded into a modelling framework, SIMPLACE (Scientific Impact Assessment and Modelling Platform for Advanced Crop and Ecosystem Management). The simulations were run using a cassava variety (TME 419) and historical weather data (1995–2010). Yield gap was estimated as a difference between simulated water-limited yield and farmer's yield (i.e., observed yield), whereas, biomass gaps were estimated as a difference between a simulated water-limited condition and the simulated actual biomass (i.e., under water and nutrient-limited condition). To examine whether variations in crop yield and biomass were related to variations in a specific climate variable, a multiple linear regression was performed for each district-crop combination with yield as the dependent variable and radiation, mean temperature and precipitation as independent variables. The estimated DM yield gaps were 8.1 Mg ha⁻¹, 6.4 Mg ha⁻¹, and 4.0 Mg ha⁻¹ in Edo, Ogun and Kwara states respectively, whereas, DM biomass gap was 10.8 Mg ha⁻¹, 9.7 Mg ha⁻¹, and 3.6 Mg ha⁻¹ in the respective states. Average farmer's yield could be increased by 176.4 %, 104.7 % and 80 % respectively in the abovementioned states under water-limited conditions. The spatial and temporal variability in cassava yield gap and biomass gap was not correlated with the climate variables (i.e., precipitation, radiation, minimum and maximum temperature) during the crop growing period. Closing the yield gaps will require in the first place adequate supply of nutrients, and reliable seasonal weather forecasts would be required to allow farmers to manage each seasonal potential, i.e., overcoming season-specific yield limitations.

Keywords: Cassava, LINTUL5, Nigeria, variability, yield gap

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Potential for Productivity Improvements of Wheat Crop by Means of Irrigation Optimisation in Lower Kabul River Basin, Afghanistan

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Afghanistan lies in the arid to semi-arid climatic zone, where efficient irrigated agriculture is the only hope to meet the locally growing food demand. Around 90 percent of irrigated land across the country is being managed conventionally which is associated with unsustainable practices resulting in to the inefficiencies and poor productivity in the system. Therefore, the purpose of this study was to assess the current water productivity of wheat crop under the conventional irrigation system to simulate potential options for improvement in water productivity. The current study was carried out in the Attawor irrigation scheme located in the lower reaches of the Kabul River Basin (KRB). The scheme has a command area of 260 ha, around 23 % of which remained uncultivated due to insufficient use of available water for irrigation. The field work for this study is split into two distinct categories: (i) the conventional irrigation system was monitored from Nov-2016 to May-2017 by measuring field-inflow to the research plots. (ii) AquaCrop model was used to simulate the possible irrigation optimisation options for the scheme level operation. For conventional irrigation, the average water productivity was 2 kg m^{-3} and the water use efficiency was in the range of 0.58–0.66 kg m^{-3} GI (gross inflow). While looking at the farm application and water productivity, there is great potential for expansion of irrigated area with the existing water, provided some farm level interventions through technological incentives to the farmers as well as infrastructure development are made. With the available water at scheme level, the AquaCrop simulations show that by adopting deficit irrigation and irrigating the crop when the soil moisture content depletes to 130 % of the available water, the dry yield can be increased up to 3.35 kg m^{-3} from the existing 1.2 kg m^{-3} . The available water in Attawor irrigation scheme has a potential to irrigate about 474 ha of land at field capacity level and at unstressed crop conditions. The findings of this study will be helpful for on-farm policy development and raising crop-water productivity and eventually attain the “more crop per drop” slogan to meet the local food demand.

Keywords: Afghanistan, AquaCrop, conventional irrigation, irrigation optimisation, on-farm water management, water productivity, water use efficiency

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Farmer's Perception Regarding Effectiveness of Drip Irrigation System in Attock, Pakistan

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Agriculture is consigned as the most important element of Pakistan. It contributes 20.9% to GDP and almost 43.5 % of the entire labour of the country is involved in this sector. It supplies total 60 % of its contribution in the economy by exports and provides raw materials for different industries. Pakistan has abundant water resources, but the misery is that we are not getting proper benefit from these resources. The only way to overcome this situation is to increase water productivity by adopting modern and efficient technologies for sustainable agriculture, which can lead to poverty reduction, profitability and improved food safety with job opportunities. Drip irrigation, water is supplied to the soil with the help of mechanical devices called as the emitters (located on water pipes along selected points). The two types of methods used in drip irrigation technique are surface drip irrigation system (water is delivered at or near the root zone of plants, drop by drop) and subsurface drip irrigation system. We aimed at obtaining information about the awareness of farmers regarding new techniques of irrigation system use in Pakistan. In the year 2015 the questionnaire data was gathered from 120 farmers who came mainly from the Attock district (89.2 %), region Punjab. Their analysis was carried out using SPSS Software. About 45.0% of farmers were old aged (>50 years old). About one-third of respondents (34.2 %) had a bachelor's degree. More than one quarter (28.3 %) had five years of farming experience. One-third (33.3 %) reported sand and clay type of soil in their field. The majority (69.2 %) were small farmers (< 12.5 acres) and only 3.3 % had large farm (>25 acres) size. The vast majority of respondents (84.2 %) believed that the drip irrigation system should be accepted. One third of respondents (38.3 %) said their work ratio was reduced to 1: 3 while less than one-third (32.5 %) of respondents said their work ratio had dropped to one quarter. In Pakistan agriculture this would be advisable because it minimises evaporation and water drainage. Through this system fertilisers can be delivered which helps in improving yields.

Keywords: Irrigation, Pakistan, questionnaire, sustainable development, water use

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Analysis of Drought Impact on Sugarcane Bagasse Based Electricity Generation under Climate Change Scenarios

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The Rio dos Patos Basin in the Cerrado Biome in Brazil is experiencing land use change from (degraded) pasture to sugarcane fields. While the Cerrado has a low share of land under sugarcane cultivation (2 %), it contains half of Brazil's sugarcane area and presents the highest sugarcane expansion rate due to land availability, flat topography and climatological characteristics. Sugarcane in Brazil is a relevant crop for sugar and biofuel production and, nowadays increasingly, for electricity production. Electricity demand in Brazil is covered mostly by hydropower plants (65 %). However, during dry and low river discharge periods, thermal power plants (oil and natural gas) cover most of the gap (14 %). Some sugarcane mills had experience selling electricity surplus prior 2005, when the first auction to 'new energies' was held. Thereafter, electricity generation based on sugarcane bagasse covers 8 % of annual demand, mostly delivered during dry season. Recent unprecedented drought events in Brazil, showed the electricity production vulnerability to droughts. Drought risk assessments including weather trend analysis and climate change scenarios can help to identify regions at risk and help to point opportunities to better cope and adapt to future drought events. In this context, the potential of sugarcane bagasse based electricity generation was evaluated in the Rio dos Patos basin. Weather data from 36 stations within the area and downscaled climate change projections under RCP 4.5 showed a decrease on precipitation jeopardising water availability. Using the Soil & Water Assessment Tool (SWAT) two scenarios were modelled: 1) without sugarcane expansion and 2) with 45 % expansion to sugarcane suitable land. Drought impacts on sugarcane and electricity production will be discussed under the mentioned scenarios. Considering the biome susceptibility to similar drought events, it is important to consider different adaptation strategies for both, sugarcane crops and energy generation, towards energy and water security.

Keywords: Cerrados, climate change, drought risk, energy, sugarcane

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Pearl Millet Yield Stability and Susceptibility to Abiotic Stresses in Semi-arid; A Modelling Perspective

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Over 500 million people depend on pearl millet for their lives worldwide. The crop is reported to be resilient to climate change due to its inherent adaptability to drought and high temperatures. These traits make pearl millet a very important crop in fighting hunger. However, the performance and resilience of pearl millet to different scenarios of future climates have been rarely explored in sub-Saharan Africa. Data from experiments conducted in two consecutive seasons (2015/2016 and 2016/2017) to determine the yield responses to different fertiliser application levels for Okoa pearl millet variety in Dodoma a semi-arid region in Tanzania were used to calibrate and validate the DSSAT model (CERES-Millet). A validated model was evaluated for 49 synthetic scenarios of climate change constructed by incremental method on historical series of observations, with temperature increments ranging from +0.5 up to +3.0°C and precipitation changes from -30 up to +30 %. Nine planting dates from very early planting 5th December to late planting 25th February after every 10 days were used for simulations of pearl millet yields response to the synthetic scenarios. Results show that the model reproduced the phenology and yield of Okoa pearl millet cultivar with relative root mean square error (rrmse) values for calibration (anthesis days (0.0 %), maturity days (0.8 %), tops weight (7.3 %) and grain yield (6.4 %)) and validation (anthesis days (2 %), maturity days (1.2 %), tops weight (3.5 %) and grain yield (11.8 %)). From evaluation, the yield response surfaces indicated that both very early and late planting dates produced lower yields with a higher risk of crop failure. The best planting window with stable yield was between 25th December and 15th January. Our results demonstrate that Okoa pearl millet variety planted before or after best planting window is susceptible to abiotic stresses under the constructed scenarios.

Keywords: Climate change, DSSAT CERES-Millet, pearl millet, planting dates

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Organic Crop Productivity Demonstration Using Tillage and Biofertiliser Management Approaches at Kulumsa/Arisi, Southeastern Ethiopia

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Modern crop production consider systemic knowledge based farming system which focused on nutrient balances, soil fertility and crop health effects. Such integrated crop management approaches are seldom practised in Ethiopia. Particularly, in the Arsi region farmers mainly grow wheat (75–90 %) and to a smaller extent of some other crops. Most farmers owing average farm-size of 1–2 ha have no understanding of modern organic farming strategies and also rarely use external farm inputs. Most of the training and support is on increasing external farm input. Hence, Green innovation Center/ GIZ funded EIAR initiated Crop Productivity Demonstration in Organic farming systems approach in Kulumsa/Arisi Region in 2016.

A total of 20 ha were allocated for the project by KARC. Interventions were deep plowing of the site and soil harmonisation using planting of alfalfa and Lathyrus seed collected from local vendors. Then all the planted biomass were converted to the soil using second heavy plowing before planting of organic crop productivity demonstration trials.

Non-replicated different separate sets of large block field experiments were undertaken in 2017 main cropping season. Tillage type experiments using mechanised and oxen plowing treatments were compared in faba bean and tef demonstration fields of 2.28 ha in each crop. With respect to tillage, faba bean productivity was higher in oxen plow treatments as compared to tractor. Contrarily, despite the insignificant differences, the two bio fertiliser strains application gave better faba bean yield with tractor than oxen plowed field. Tef agronomic yield was better in oxen than tractor plowed field, that may be associated to the crop required compact seed bed which failed to have in heavy plowing using tractor. Similarly, five crops were evaluated for their productivity in organic model farm experiment under green manure and with additional decomposed animal manure each in 4.5 ha (0.75 ha for each crop). Organic wheat productivity (3300 kg ha⁻¹) showed above national average (2.4 t ha⁻¹) with great optimistic future. Similarly, productivity of potato was 24,444 kg ha⁻¹ and that of fresh biomass of alfalfa was 11,640 kg ha⁻¹ and other tested crops were above the national average productivity levels.

Keywords: Alfalfa, *Eragrostis tef*, faba bean, organic farming, tillage

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Effects of P Nutrition and VPD on Rice Leaf Morphology and Photosynthesis

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The first time in a decade, global hunger is on the rise again driven by conflicts and climate change. The rice cultivation system as such is a significant contributor to greenhouse gas emissions and a major consumer of phosphate (PO_4^{3-}) a non-renewable resource and the most limiting nutrient for plant growth after nitrogen. In order to meet the sustainable development goals, rice production has to be increased by 50–110 % and at the same time, the impact on environment and water usage has to be reduced. To address this issue, a greenhouse experiment was conducted comprising 32 rice plants of two varieties (IR64, Chomrong). Plants were grown in a hydroponic system and manipulated using a nutrient solution with two different phosphate levels (low and optimal P) and two levels of vapour pressure deficit (low and high VPD). Destructive samplings, leaf phosphate analysis, stomatal imprints were performed during the vegetative phase of the plants. Additionally, gas exchange measurements were conducted on young and on older leaves.

Plants subjected to the low phosphate treatment had a significantly smaller leaf area, a lower leaf phosphate concentration, higher root to shoot ratio and generally a higher stomatal density.

While in young leaves P nutrition did not significantly affect assimilation rates, in old leaves reduced P nutrition led to higher assimilation rates in IR64 at high VPD due to higher stomatal conductance. Since under P deficiency, inorganic phosphate (Pi) is translocated from old to young leaves, stomatal control is probably lost in highly P deficient old leaves of IR64. In contrast, Chomrong was able to maintain its stomatal control even in its old leaves, which could be an interesting trait for plant breeding for P limited environments.

Keywords: Climate change, phosphate, phosphor, photosynthesis, resource management, rice, stomata, sustainability, vapor pressure deficit

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Mechanical Weed Control in Cassava: Effects on Weed Biomass, Labour Requirements and Root Yields

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Weed control is a major labour input in cassava production and commonly burdens women and children with drudgery of bending down and weeding with short handled hoes. Chemical weed control has not been investigated as well as in other crops and mechanical weeding is uncommon. Multi-location trials in major Nigerian cassava growing areas investigated if manually operated or engine driven weeders can attain weeding quality and root yields as manual weeding. Over two years 7 treatments were tested: short handled hoe (SHH), long handled hoe (LHH), rotary weeder (RW), Spike weeder (SW), small motorized tiller (SMT), large motorized tiller (LMT) and motorized brushcutter (BC). Weeding was conducted at 4, 8, 12 and 24 weeks after planting, cassava density was 12,500 plants m^{-2} . Net-plots measured 4 × 8 m. Each implement was tested on ridged versus flat soil and by female and male operators. The rotary and spike weeder and brushcutter were eliminated due to poor quality and high time requirements (60–90 minutes plot $^{-1}$). The LMT was too difficult to handle. SHH, LHH and SMT required 30–40 minutes plot $^{-1}$. Ridging the soil was an advantage reducing weed biomass. Small plot data appeared to underestimate the time requirement and did not tally with data reported at field level. In 2017 four large plot trials (1250 m 2 per plot) were established comparing the SHH and the SMT on ridged soil. At first and second weeding the SMT required significantly less time to weed than the SHH. Cassava root yield was not significantly affected by the weeding implement or the operators' sex. However, fields weeded by male operators attained higher yields (19.7t ha $^{-1}$ fresh roots) than female operators (15.9t ha $^{-1}$ fresh roots). The difference between the implements was marginal (17.9t ha $^{-1}$ SHH versus 17.7t ha $^{-1}$ SMT). The larger time requirement rendered the SHH the more cost intensive weeding method despite the fuel requirement of the SMT, yet not regarding the purchase cost (600 US\$) and depreciation of the SMT. Labour requirements in the large plots were higher than those measured in small plots. Delayed weeding caused weeding time to increase up to 4 fold.

Keywords: Labour time, motorized weeder, weed control

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Nitrogen Fixation in White Yam (*Dioscorea rotundata*) Using Naturally Abundant ^{15}N

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White yam (*Dioscorea rotundata*), a tuber crop cultivated and utilised as a staple food in West Africa, plays an important role in the daily diet of millions of people in the region. However, in spite of the growing local demand for white yam, little progress has been made in increasing supply by optimising fertilisation methods to improve yield. Several experiments conducted throughout the region to determine the optimal quantity of nitrogen fertiliser needed for the crop arrived at contradictory conclusions, suggesting the need to take a different approach to elucidate the nitrogen absorption mechanism and to apply it to cultivation. Here we report on the nitrogen absorption mechanism in white yam with a special focus on its nitrogen fixation ability using naturally abundant ^{15}N ($\delta^{15}\text{N}$).

A field experiment was conducted at the International Institute of Tropical Agriculture in Ibadan, Nigeria using six white yam accessions with squash (*Cucurbita moschat*) plants as a reference. Experimental plots with three replicates for each accession were prepared without the application of fertiliser in a randomised block design. The percentage of plant N derived from atmospheric N_2 (%Ndfa) was calculated based on $\delta^{15}\text{N}$ values.

A wide range of variation was observed in %Ndfa values among the six white yam accessions. The highest value was accession DrDRS074 (45.5 %) and the lowest was DrDRS042 (-4.7 %). Moreover, the %Ndfa of accession DrDRS074 (45.5 %) was statistically significant than that of DrDRS058 (7.2 %) and DrDRS042 (-4.7 %). The results obtained in this study suggest the ability of white yam to fix atmospheric nitrogen; however, intra-specific variation must be also considered. To ascertain the nitrogen fixation ability of different white yam varieties, further research on the presence of symbiotic bacteria as well as the effect of nitrogen fixation on plant growth should be conducted.

Keywords: Low soil fertility, nitrogen fixation, white yam

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Experimental Substantiation of the Use of Agricultural Waste in Obtaining Biodiesel

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The territory of the Turkestan region of the Republic of Kazakhstan is the most promising for growing pumpkins. The climate of the region is characterised by high spring-summer-autumn temperatures, and the well-developed root system of this melon crop is perfectly adapted for cultivation on irrigated lands. The peel formed during pumpkin processing can be considered as a promising specific raw material for the production of products with higher value added, for example, as an energy source. This study substantiate the use of the rind and pumpkin seeds of *Cucurbita pepo* L. as a potential source of biofuels.

To test the effectiveness of the technique, an experiment was conducted in the laboratory. The rind of *Cucurbita pepo* L. (Cucurbitacea) was washed with detergent, rinsed with clean water, reduced in size $0.5 \times 0.5 \text{ cm}^{-2}$ and dried in a Nabertherm muffle furnace at 110°C for 72 hours. After drying, the peel was crushed using a hand blender (Philips HR 2102 White).

The sample was extracted with methanol:chloroform (1:2) according to the Folch method. The solid and non-lipid material was removed, the solvent was dried. As a result of the experiment, it was found hat per 100 grams of pumpkin peel there are 3 grams of the total lipid fraction, and per 100 grams of seeds 8 grams. Based on the experimental results obtained in this work, it was concluded that the potential use of pumpkin peel waste as a biofuel is possible on an industrial scale in the Republic of Kazakhstan.

Keywords: Biodiesel, biofuel, Folch method, pumpkin

Architecture of Potato Roots (*Solanum tuberosum*, group Phureja) in Early Stage

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We evaluated the morphological response of 5 varieties of diploid potato (*Solanum tuberosum* L., Phureja group) subjected to *in vitro* conditions. The hypothesis proposed was based on the root architecture of each of the varieties, presenting a differential response in the angle of insertion as a diagnostic character associated with tolerance to water stress.

The objective of this study was to determine differences in the endogenous early response of the tolerant and non-tolerant materials to water stress previously studied. For this a morphological characterisation was carried out.

The experiment was carried out in the Faculty of Agrarian Sciences of Universidad Nacional de Colombia, Bogotá headquarters with geographic coordinates 4° 35'56"57 N and 74° 04'51"30 W and altitude of 2,600 meters above sea level. Treatments were arranged in a completely random design with three repetitions. Three varieties of *S. tuberosum* group Phureja susceptible to water deficit were evaluated: Dorada, Ocarina and Colombia, and two tolerant to water stress: Violet and Milagros.

They were evaluated during 4 months with an interval of 3 days to measure the variables of angle of insertion, average length of primary roots and length of secondary roots, maximum length, number of roots and number of secondary roots and perimeter area. As a result, the description of the potato root architecture of the five contrasting varieties was obtained with respect to the response to water stress in the field, whereby no differences were found in the variables evaluated.

Keywords: Root architecture, root morphology, *Solanum tuberosum*, drought tolerance, *in vitro* propagation

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Agricultural Extension for the Production of Quinoa in the Andean Highlands of Perú

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In the southern Andes of Perú, particularly around Lake Titicaca up to over 4000 m altitude, the Inca domesticated many plant species for their daily diet. These plants include quinoa (*Chenopodium quinoa*), known since 7000 years. Quinoa causes increasing worldwide demand due to its nutritive value. Quinoa has been considered by the FAO as one of the crops for food security because of both the nutritional quality, and its ability to grow in difficult environments, showing tolerance to frost, hail, snow, heat, salinity and drought. Quinoa seeds are rich in protein, dietary fiber, B vitamins, and dietary minerals in amounts greater than in many grains. It is gluten-free. With hundreds - may be more than three thousand - native varieties, Perú and Bolivia present the highest genetic diversity of quinoa, and in 2008 contributed to 92 % of world production, followed by USA, Ecuador, Argentina and Canada. In 2012, Perú produced 44 000 tons on 38 500 hectares. Since 1996, the NGO Asociación Peruana para la Promoción de Desarrollo Sostenible (APRODES; www.aprodes.org), with support from national and international institutions, assists farm families with social, economic and environmental development. APRODES is oriented towards the entire country. In the south, APRODES began in 2007 with production and commercialisation of Andean crops (kiwicha, quinoa, tara, chia, aguaymanto), in addition to food security, livestock production and basic sanitation. There, APRODES has been working with over 800 beneficiary families, distributed over more than 25 Andean communities. APRODES contributes to personal, family and social well-being, promotes sustainable economic development, and protects the environment and sustainable management of natural resources. APRODES improves the nutrition and health of vulnerable families with emphasis on child population from a focus on disease prevention. Recently, in contribution to agricultural extension, APRODES organised a workshop for extension personnel on the design of a field book (Cuaderno de Campo) for organic quinoa production at Izcuchaca, Provincia de Anta, Departamento de Cusco.

Keywords: Agricultural relevance, agricultural extension, Andean highlands, biodiversity, cultural relevance, NGO APRODES, quinoa (*Chenopodium quinoa*), sustainable development

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Socioeconomic and Technological Profile of Rice Growers in São Mateus do Maranhão Municipality, Maranhão State, Brazil

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This study aimed to study the socioeconomic and technological profile of rice growers in São Mateus do Maranhão, Maranhão state, Brazil. Therefore, structured questionnaires were applied, as well as the use of secondary data with bibliographical and documentary research. In order to determine the number of producers that would be interviewed, a sample was defined based on IBGE's agricultural census data (2017), which pointed out that the municipality of São Mateus do Maranhão has 269 rice growing farms. From this population, a sample of 75 farmers were interviewed (95 % of confidence level, with 10 % error). With the data collection, it was possible to observe that the activity of rice production in São Mateus do Maranhão municipality is developed by small, medium and large producers. From interviewed rice growers, 73 % are organised in associations, 24 % in societies of limited responsibility, and 3 % in isolated family business. From all interviewed farmers, 31 % grow rice on leased land. Also, 12 % of rice growers lease part of their land to other farmers to grow rice. Rice growers use two cropping systems: (a) the rainfed paddy cultivation in areas with favourable rainfall distribution (96 %); and (b) the irrigated paddy rice (4 %). The results show that the marketing of production and acquisition of new technologies represent the main obstacles for producers, especially the small ones, who have difficulties in obtaining technologies to improve the activity and little access to marketing channels available in the region. This shows to the need for public policies related to technical assistance directed at marketing channels and, above all, effective technical monitoring.

Keywords: Associations, marketing, technological innovation, rice cultivation

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Effect of Farming on Watershed Area of Inle Lake, Myanmar

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The present research was carried to unfold the awareness of Inle Lake dwellers on the adverse effects of farming activities on the watersheds. Study areas comprised seven villages in four village tracts around the lake. A total of randomly selected 81 farmers were interviewed during March 2016. Information from experts and printed materials from the department of agriculture were also collected. The dependent variable, farmers' awareness of certain environmental effects of farming was further split into six dimensions to get a clear picture of the awareness. Probit regression analysis was performed to determine the determinants of farmers' awareness of certain environmental effects of farming on the watersheds. Findings show that 72, 100, 23, 81, 17 and 59 % of the sampled farmers are aware of sedimentation increase, water quality declining, biodiversity loss, fisheries resources decline, drought increase and air pollution increase, respectively, that are caused by farming activities in the lake areas. They have the highest awareness of water quality declining and the lowest awareness of drought as a consequence of farming activities. However, awareness on different aspects of adverse farming effects on the watersheds is influenced by different factors. In general, education, family size, farm size, frequency of manure application and frequency of pesticide application contribute to improve the farmers' awareness of adverse farming effects. On the other hand, cropping intensity (mono-cropping) and duration of high yielding variety (HYV) cultivation negatively impact on this awareness. However, age does not have any significant influence to build awareness of adverse farming effects on the watersheds. This study emphasises the increased awareness as a prerequisite to discourage farmers to practice such farm activities that could potentially harm the watersheds. In order to increase the farmers' awareness of adverse farming effects, government should invest to improve the educational qualifications of the farmers regarding adverse environmental effects of farming activities. Agricultural extension services should be focused on delivering supports to the farmers on increasing the manure (organic fertilisers) application and cropping intensity (indirect way of increasing farm size in terms of total cropped area).

Keywords: Environmental awareness, farmers' attitude, farming, watershed area

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Contribution of Resilient Agronomic Techniques to Increased Maize (*Zea mays* L.) Productivity on Degraded Dry Lands in Karamoja, Uganda

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Application of selected resilient agronomic techniques on degraded lands enhanced increased productivity of maize for smallholder farmers in Karamoja. The land is structurally sandy, poor in soil fertility with high moisture deficit due to drought stress. Technologies for improving crop productivity were adopted, and focused on maize productivity due to food and income importance to smallholder farmers. Thus enhancing improved productivity for smallholder farmers, explored interventions aimed at (i) assessing agronomic techniques enhancing biomass development and crop growth on degraded land (ii) Identify drought stress tolerance mechanisms ideal for plant survival (iii) Assess plant nutrition accumulation from soil fertility replenishments and (iv) quantify maize yield. Applied agronomic techniques comprised of *Zai* pits, furrows and integration of velvet bean legume (*Mucuna pruriens*) for revitalisation through biodegradation. Results showed improvement in biomass development with 42 % increase in plant vigour, 17–50 % (leaf area), 12–19 % (stem), 14–30 % (root exploration) for *Zai* pits than furrows and legume integration techniques. Leaf folding ranged significantly from 115°–73° in *mucuna* intercrop indicating mechanisms for maintaining leaf turgidity, and 42 % stay green from leaf senescence for plant survival during drought stress. Maize leaf chlorophyll was significantly quantified at 39.3 mg g⁻¹ (furrows) and 45.2 mg g⁻¹ (*Zai* pits) indicating proper nutrient uptake correlating positively with plant vigour and leaf area. Maize output across agronomic techniques varied significantly with *Zai* pit techniques enhancing the highest yield at 3.1 MT ha⁻¹, furrow (2.6 MT ha⁻¹) compared with sole maize (0.74 MT ha⁻¹), indicating an increase of 40–65 % in maize productivity. Therefore growing maize in *Zai* pits and furrows on degraded lands enhanced increased productivity hence food security.

Keywords: Degraded land, furrows, maize, resilience, *Zai* pits

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Plant genetic resources - a tool to fill gaps and remove traps

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Defining Thresholds for Identifying Genetically Redundant Accessions within CIAT's Global Cassava Collection

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Crop diversity is critical for food security, climate adaptation, dietary quality and poverty reduction. Cassava is a critical source of carbohydrates for 500 million people in Africa and elsewhere. The International Center for Tropical Agriculture conserves the globally largest collection of cassava (*Manihot esculenta*) and its wild relatives (6,155 accessions). The collection, currently conserved in-vitro under slow-growth conditions, will be cryopreserved once genetically redundant accessions have been removed. We conducted an experiment to determine thresholds for identifying genetically redundant accessions by genotyping technical and biological replicates from a group of accessions. Twenty-five cassava accessions were selected for DNA extraction. Three types of replicates were analysed to quantify genetic distances (Gd): (i) different individuals from the same accession "Individual-Reps", (ii) different DNA samples extracted from the same individual "Extract-Reps", and (iii) the same DNA sample analysed twice "DNA-Reps". In addition, 17 accessions were randomly selected from a core collection to compare Gd between replicate pairs using a more diverse group of accessions. DNA samples were analysed using the DArT-seq genotyping platform (DArT-PL) to generate dense profiles of SNP and 'in-silico-DArT' markers (the latter being the presence/absence of sequence-tags in the genome representation). Marker identification and allele-calling were performed using DS14 software (KDCompute plug-in system). A total of 188 samples and 114,545 markers were obtained (59,519 SNP/55,026 'in-silicoDArT'). SNP markers were used to compute distance matrices after applying additional marker-specific quality filters, such as sequencing depth, call rate and polymorphism content. The variation in the average Gd between replicate pairs (Individual-Reps, Extract-Reps and DNA-Reps) was used as a criterion to adjust marker-quality thresholds to retain a maximum number of markers while producing close-to-zero genetic-distance estimates for replicate pairs. The thresholds values determined in this study will be used to identify a genetically non-redundant subset of DArTseq-characterised accessions for cryopreservation to reduce long-term conservation costs.

Keywords: Cassava, genetic diversity, genotyping

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Seed Distribution in Rural Communities of Central America

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The importance of *in-situ* agricultural biodiversity has increased over the last two decades. Local crops and varieties have been lost at an alarming rate since the 1970s. Efforts to preserve them ex-situ in germplasm banks are just a partial solution: without a continuous cycle of planting and selection, agricultural biodiversity stops its dynamic cycle. Since the beginning of agriculture, seed exchange between farmers has been one of the main mechanisms of distribution and conservation of agricultural biodiversity.

In this study, we tracked and mapped how rural communities are preserving and exchanging seeds. We analysed and compared how seed networks operate for: 1) grains and legumes; 2) horticulture and vegetables; 3) tubers and root crops, and 4) forest and fruit trees. Using a structured survey, the research took place in a total of 18 rural communities in Belize, Honduras and Panama. Using a “following the seed” method, the total number of farmers surveyed was 427. Some of the results indicate that the grains and legumes and the tubers and roots networks were more dynamic and decentralised in the three countries when compared to the horticulture and vegetables networks now controlled by few actors.

Maize and bean varieties were selected, preserved and distributed between farmers with high intensity and without the need for external actors. In parallel, horticulture and vegetable networks are heavily concentrated, and their seed distribution is dependent on external actors such as NGOs, government agencies or private enterprises. The difficulties to select and preserve seeds of different crops is one of the main causes of a concentrated network dependent on external actors. If *in-situ* agricultural biodiversity is to be preserved in these countries, there is a need for greater understanding of how and why farmers are preserving and exchanging seeds.

Keywords: Central America, crop biodiversity, seed networks

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The Contribution of CIAT Genebank in the Development of High-Iron Bean Varieties and Farm-Level Impacts in Rwanda

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Genebanks play an essential role in a world where a substantial part of agricultural biodiversity has been lost from farming habitats, malnutrition persists as the global population continues to rise, and farm productivity is vulnerable to climate change. We demonstrate the importance of the genebank of the International Center for Tropical Agriculture (CIAT) in the development of seven iron-biofortified climbing bean varieties (CAB2, RWV3316, RWV3317, RWV3006, RWV2887, MAC44, MAC42) and the impact of their adoption on farm households in Rwanda. First, we link iron-biofortified climbing varieties directly to the genebank through pedigree analysis and key informant interviews with the breeders who developed them. Second, we apply an econometric model to test the impact of their adoption on the yield, consumption and purchase of beans by farming households in Rwanda. Analysis is based on a dataset collected from nearly 1400 households in 2015 by Harvest Plus. We find that the scope of the genetic diversity housed in the bean collection at CIAT was fundamental to developing successful iron-biofortified beans. In contrast to the findings of Vaiknoras (2019), which focused on a most extensively adopted variety of bush bean, we found no statistically significant effects. There could be various explanation for these results, such as the comparatively lower rate of adoption of climbing beans or their different characteristics and the difference in the way they are harvested. Our results suggest that it is possible to track the journey of an accession from its introduction in the genebank to its final use by farmers. Further research is needed to understand why these climbing varieties had less impact than the bush variety previously studied.

Keywords: Breeding, genebank, high-iron beans, malnutrition, Rwanda

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Screening Sweetpotato Crop Wild Relatives for Sweetpotato Virus Disease Resistance

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Sweetpotato Virus Disease (SPVD) is a major constraint to sweetpotato production worldwide and particularly in sub-Saharan Africa. SPVD is caused by the synergistic interaction of the whitefly-borne Sweetpotato Chlorotic Stunt Virus (SPCSV) and the aphid-borne Sweetpotato Feathery Mottle Virus (SPFMV). Approaches to control SPVD are limited to phytosanitary measures and the use of virus-free planting material. Due to the lack of extreme natural resistance to SPVD in the sweetpotato gene pool, crop wild relatives are a potential alternative source of resistance genes. However, no resistance could be found in species of the *Ipomoea* series *Batatas* (Choisy) D.F. Austin complex, the group of crop wild relatives most closely related to sweetpotato. To evaluate sweetpotato crop wild relatives for resistance to SPCSV and SPFMV 53 accessions of nine species belonging to the *I. batatas* complex were subjected to repetitive cycles of grafting with infected stem cuttings and subsequent enzyme-linked immunosorbent assay (ELISA) screenings. Resistance of accessions that remained negative to SPFMV or SPCSV was finally validated by grafting plant material on indicator plants (*I. setosa*) followed by ELISA analysis. Two *Ipomoea cordatotriloba* accessions (CIP 460296 and CIP 460164) were identified showing stable resistance to SPCSV and one *Ipomoea tiliacea* accession with resistance to SPFMV (CIP 460531) was found. No resistance to both viruses was detected. These findings demonstrate that sweetpotato crop wild relatives are a potential source of true and durable resistance to SPVD useful for sweetpotato pre-breeding initiatives. Since crossing barriers of species of the *Batatas* complex with sweetpotato exist further research is required to explore pre-breeding approaches such as the use of bridge species.

Keywords: *Ipomoea* series *Batatas*, pre-breeding, sweetpotato chlorotic stunt virus, sweetpotato feathery mottle virus, sweetpotato virus disease

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Potential for Domestication of *Borassus aethiopum* Mart.: A Wild Multipurpose Palm Species in Sub-Saharan Africa

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Borassus aethiopum Mart. is a dioecious palm species native to mainland Africa. It is a multipurpose tree daily used by local communities but is unfortunately threatened by anthropogenic pressures in many parts of Africa. Fruits and young shoots represent the most exploited parts putting the species at risk. Since the domestication of species offers a good alternative for its long-term benefit, the present study aimed at assessing the environmental-induced diversity in morphological traits of fruits and evaluated differences in growth and weight of hypocotyls from one-seeded, two-seeded as well as three-seeded fruits from different provenances in the three climatic regions of Benin. A total of 5,400 fruits were collected from 180 trees in six populations and fruit and tree morphological traits were measured. A randomized complete block design with three replications was used for the experimentation in each climatic region. The results showed that variation in fruit morphological traits was not influenced by climatic regions. Furthermore, the greatest variation (65 - 94 %) in fruit morphological traits was located at tree level, highlighting that selection of many fruits and individual trees within a few populations would capture a large variation of fruit traits. Tree diameter at breast height (18.5 - 52 cm), total height (6.4 - 19.6 m) and bole height (4.8 - 17.6 m), fruit length (7.00 - 20.50 cm), dry weight (98 - 2552 g), shape index (0.59 - 2.80), and number of seeds per fruit (1 - 3) were the most discriminative traits of the studied populations. Clustering of the trees resulted in five different morphotypes based on discriminating traits. Morphotypes 1 and 2 showed high performance for fruit and seed production and are consequently recommended for selection and breeding programs. Irrespective of the provenances, the best performance of hypocotyls were observed in the humid region. The study provides important baseline information for domestication and sustainable conservation of *B. aethiopum* in Benin.

Keywords: Climatic regions, domestication, hypocotyl, morphological traits

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Observations on Seed Embryo and Germination, Seedling Morphology and Development of *Vitellaria paradoxa* (C.F.Gaertn.)

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The pyrophytic features and high longevity of shea tree (*Vitellaria paradoxa*) make it an excellent species for combating desertification and mitigating climate change in sub-Saharan Africa. In this study, our aim was to describe precisely the cotyledon morphology, seedling development process and seedling morphology that account for cryptohypogeal germination of the species. To identify the embryonic axis, fresh and partially dry seeds were deshelled and their distal ends transversely cut off. Cut seeds were immersed in 1.0 % tetrazolium chloride (TTC) solution for 24 hours and kept in the dark for staining. To study cotyledon morphology, 50 seeds were deshelled, air-dried for 3-5 days and split open from the distal end. Another batch of 50 seeds were sown directly. The sprouted seeds or seedlings were sampled at 5-day intervals and their cotyledonary tubes sectioned to observe morphological and anatomical features. To study seedling development, 180 seeds were classified into three groups based on their sizes and then sown on seedbeds in randomized complete block design with 60 in each of the 3 replicates. The TTC solution stained the proximal ends of only the fresh seeds. Morphologically the seed bears a cotyledonary raphe, which lies vertically with distally schizocotylous and proximally syncotylous cotyledons. Seed size significantly ($P < 0.05$) affected the various stages of seedling development. Large seeds sprouted earlier (7 days) followed by seedling emergence within 61 days, while small seeds sprouted almost a week later (12 days) with seedling emergence within 75 days. The location of the embryos at the proximal ends cause germinating seeds to produce long cotyledonary tubes which bury the plumules deep into the soil as a protection against bushfires. This germination study will enhance nursery establishment for plantation development of *V. paradoxa*.

Keywords: Cotyledon, cryptohypogeal, establishment, germination, pyrophytic, seedling emergence, shea, *Vitellaria paradoxa*

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Constraints and Opportunities of Cassava Seed Systems in South India: An Exploratory Case Study

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In India, most cassava is produced in the federal states of Kerala and Tamil Nadu. While the crop is generally valued for being well adapted to marginal cropping conditions, the cassava mosaic disease (CMD) is widespread in India, resulting from the indiscriminate use of infected planting material, a lack of commercial interest, and the long-prevailing non-availability of improved cassava varieties. Under the Indo-Swiss Collaboration in Biotechnology (ISCB), Indian and Swiss research institutes have increasingly worked together on the development of improved CMD-resistant cassava varieties. Yet, as for many other tuber crops, cassava propagation generally follows a vegetative approach, resulting in a relatively slow seed dissemination. Hence, the pressing question is how new varieties can be effectively disseminated within reasonably short time, so that farmers, the ultimate beneficiaries, can access them.

In 2018, qualitative in-depth interviews and group discussions were conducted with cassava farmers, breeders, extension and agricultural scientists, agricultural economists, and cassava processing industry representatives in Kerala and Tamil Nadu to first, identify the main constraints and bottlenecks for the dissemination of new cassava varieties to farmers and second, develop recommendations to sustainably improve the dissemination process.

The research shows that cassava is generally of low and highly fluctuating economic value, which constitutes a key challenge for the development of a seed system driven by a larger demand of farmers. This is interrelated with a low willingness to pay (WTP) of farmers for new varieties, a perceived high opportunity cost (risk) of acquiring new planting material, inadequate rules and regulations for the re-use of infected seed and the legal status and support of cassava, as well as the absence of a clear mandate and adequate capacities for seed multiplication and dissemination. The study recommends a multi-perspective and multi-stakeholder approach to (i) formally clarify the mandate for planting material multiplication and dissemination, (ii) strengthen extension capacities for agricultural technology transfer, (iii) explore the potential of farmers' associations engaging as actors in an improved, functional cassava seed system, and (iv) consider changes at policy level for the re-use and replacement of planting material and the allocation of specific subsidies.

Keywords: Cassava, cassava mosaic disease (CMD), dissemination, India, manioc, multiplication, planting material, seed system

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Response of Drought-Inducible Proline Accumulation in Barley Genotypes to Seed Set and Filling

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Drought as a consequence of climate change is projected to become more prevalent in the future to cause yield decline of about 33 % in barley. In this study we focus on drought response of five different spring barley genotypes; four 2-row types with *Barke* and *Scarlett* as elite German cultivars, two introgression lines *IL143* & *IL141* which bears the ancestral allele *Pyrroline-5-carboxylate synthase1- P5cs1* and one 6-row type *HOR10151*. Plants were grown until booting stage in the greenhouse in pots with peat soil and then subjected to 18 days of well-watered (100 % field capacity) and water-stress (30 % field capacity) treatments. For all genotypes significant reductions due to the treatment were observed for phenotypic, biochemical and physiological traits. Averaged over all genotypes, a significant reduction in plant height (17 %), tiller number (20 %), spike number (56.3 %), grain number (28.8 %), spike length (19 %), grain weight (76.5 %), relative leaf water content (4.4 %), CO₂ assimilation (55.6 %), stomatal conductance (73 %), transpiration rate (63.6 %) and electron transport rate (49.3 %) was recorded due to drought. A positive correlation was found between the treatment effect on spike length and the reduction in grain number ($r=0.73$, $P\leq 0.01$) and grain weight ($r=0.37$, $P\leq 0.05$), respectively. Reduced green leaves area was observed for all genotypes, with the two introgression lines showing milder drought symptoms. The reduction in relative leaf water content was negatively correlated ($r=-0.61$, $P\leq 0.001$) with the reduction in shoot dry weight. Again, the reduction in relative leaf water content positively correlated ($r=0.65$, 0.53 , 0.51 , $P\leq 0.01$) with reductions in transpiration rate, stomatal conductance and CO₂ assimilation respectively. Across genotypes, the grain filling duration was not affected. However, preliminary MRI scans indicated that there might be differences in floret abortion among drought treated elite cultivars compared to introgression lines. The 6-row barley *HOR10151* was severely affected while *IL143* showed better drought tolerance by staying green, maintaining relative leaf water content and remaining photosynthetically active. These results support and extend recent findings that barley genotypes harboring wild variant of *P5cs1* might have an advantage in tolerating low water availability.

Keywords: Barley, drought-inducible proline, filling, seed set

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Exploring Farmers' Preference for Varietal Traits in Ethiopia: Stated Choice Analysis

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Plant breeding is one of the key tools to reduce vulnerability associated with abiotic and biotic stress challenges and improve food security. In Ethiopia, public breeding programs are releasing large number of varieties mainly based on yield superiority as the major criterion. The existing strategy follow 'one size fits for all' approach. There is a question of; do breeders really provide what farmers want? Breeding impacts depend on farmers' adoption decision. However, drought-prone sites are benefited little from breeding and new varieties are not adequately adopted.

The literature has emphasized the lack of access to improved varieties and credit constraints as the major bottlenecks. Accordingly, there exists little research on whether the variety traits are compatible with farmers' preferences. Against this background, the objective of this study is to examine whether the traits fit enough with farmer preferences located in drought-prone areas.

A choice experiment with attributes of productivity, high adaptation to stress conditions, bean color, and seed cost was used to conduct survey with randomly selected 167 beans growers in southern Ethiopia. The choice survey was supplemented with focus group studies and a separate household survey questionnaire to identify farmers' socioeconomic characteristics. Random parameter logit model was used to estimate farmers' trait preferences for variety selection.

Results from the focus group studies show that farmers have a higher propensity towards drought-tolerant varieties. The model analysis also shows that farmers have highly opted for a trait associated with adaptation to stress conditions. Furthermore, the analysis provides evidence for significant preference heterogeneity across farmers. Overall, higher preference towards yield stabilizing attributes has strong welfare enhancing arguments to set breeding priorities. This implies the need for re-orientation of the existing breeding approach to establish demand-driven and context-specific breeding strategies to enhance adoption of new varieties.

Keywords: Breeding strategy, choice experiment, common bean, drought-tolerant, random parameter logit, traits preference heterogeneity

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***Triticum araraticum*: A Wild Tetraploid Wheat Species with Potential Implications in Crop Breeding Programs**

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Wheat is one of the major crops, globally known since its early domestication in the Fertile Crescent 12000 years ago. Its evolutionary process and species diversification are of interest to many breeders. With the help of molecular markers, it became feasible to reveal the information about crop genomes and detect their genomic diversification. Our research aimed at characterising one of the least explored wheat species. This wild wheat species was first identified in the 1930s and given its botanical name *Triticum araraticum*, Jakubz in 1947 by Jakubziner, with a tetraploid genome (GGAuAu). Wheat Ararat is the wild progenitor of domesticated tetraploid *T. timopheevii* and it is included among the group of hulled wheat with tenacious glumes and disarticulated spikes. Our research was conducted on 79 different genotypes of *T. araraticum*, originated from Turkey, Iraq, Iran, Israeli, Syria, Azerbaijan, and Armenia. The genotypes were sampled from their natural habitat by H. Özkan and yet kept in the genebanks. With the implementation of a retrotransposon-based iPBS marker system, we could identify the genomic diversification among the 79 genotypes arranging them into two main clusters. Moreover, we estimated a number of phenotypic measurements, revealing that *T. araraticum* has an average plant height of 95 cm, spike length of 11.5 cm, peduncle length of 40 cm, spike weight of 1.25 gm, seed weight per spike of 0.4 gm, and a number of 30 seed grains per spike. Additionally, most of the plants required up to 115 days until starting the heading (spikes production). Our research revealed substantial phenotypic diversity in *T. araraticum*. Moreover, the nutrient analysis revealed wild wheat accessions had an average zinc content of 96 mg kg⁻¹, phosphate concentration of 5.5 g kg⁻¹, and phytate content of 15 g kg⁻¹. Hence, we concluded that *T. araraticum* accessions involved in our study showed diversification at the genomic, phenotypic, and nutritional levels ensuring the diversified genomic pool of Ararat that can help in enriching the genomic diversity of wheat cultivars if being implemented in breeding programs.

Keywords: Genomic diversification, iPBS retrotransposons-based markers, wheat evolution, wild relatives

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Large Scale Screening for Potential Abiotic Stresses Tolerant Rice Germplasm in Vietnam

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Global climate change has potentially grave affects for rice production and, consequently, global food security. Its phenomena, such as sea-level rise leading to salinity intrusion, temperature increment and unpredicted weather causing flooding and drought, occur more frequently in the irrigated intensively managed rice areas and is accounted for a 15 % decrease in rice yields worldwide. Rice production of Vietnam recently has been under the influence of the same circumstance. In order to mitigate and adapt to increasing severe unfavoured conditions, breeding for new rice varieties which effectively tolerant to abiotic stresses such as submergence, salinity and drought is a priority in the restructuring strategy of Vietnam agriculture sector. Vietnam is one of the world's genetic diversity centres of rice. Sufficient rice germplasm evaluation is considered as a crucial premise which, therefrom, facilitates effective exploitation of such gene pool for rice breeding programme in the themes of food security guarantee and climate change mitigation.

In this presented study, a panel of 146 Vietnam rice accessions that included landraces, elite and popular cultivars, and breeding lines developed from various rice breeding programme across Vietnam were screened both phenotypically and genetically. Phenotypic evaluation under unfavourable abiotic stresses identified five accessions highly tolerant to submergence, one accession moderately tolerant to 9‰ salinity and 16 accessions exhibiting potential yield performance under drought stress. In parallel, genotyping experiment using the 7K SNP Chip revealed a high diversity among screened rice accessions. Genotypes which associate with characterised genes/QTLs conferring targeted abiotic stresses tolerance were observed for most of potential rice accessions except that showing tolerance to salinity. It implies that, there are other genetic elements may involving in salinity tolerance in rice. Notably, clustering analysis based on the selected 52 SNP markers representing submergence, salinity and drought tolerance genes/QTLs also discriminated groups of landraces and improved accessions. These results provided a useful insight into the genetic diversity of Vietnam rice population.

Keywords: Drought, rice, salinity, screening, SNP, submergence

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Genetic Diversity in Napier Grass (*Cenchrus purpureus*) Collections as Revealed by Genotyping-by-Sequencing Method of the DArTseq Platform

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Napier grass is one of the most important fodder crops, particularly in Eastern and Central African countries and used as a cut-and-carry feed with high potential as a bio-fuel crop. The ILRI (International Livestock Research Institute) genebank holds a diverse set of Napier grass accessions and also has a collection contributed by the Brazilian Agricultural Research Corporation (EMBRAPA). One hundred and five accessions were subjected to genotyping by sequencing using the DArTseq platform, which generated 116,190 SilicoDArT and 85,452 SNP high-density and polymorphic markers together with short sequence reads. The short sequence reads, with an average of 54 nucleotides, were mapped to the pearl millet reference genome, which is the closest related species to Napier grass. Around 17 % of the SNP and 33 % of the SilicoDArT markers were mapped and, based on the map position, the closest genes aligned with the markers were identified and the corresponding annotation information extracted. In turn, these data were used to select candidate genes for important forage traits based on functional annotations and sequence similarity. A total of 980 highly polymorphic SNP markers distributed across the genome and mostly independent were used to assess population structure and diversity. Up to seven subgroups were identified using phylogenetic analysis and the major ones were supported by the admixture model in STRUCTURE and principal component analysis (PCA). A few representative Napier grass accessions were subsetted from the diversity with the objective to distribute a representative subset of a manageable size for adaptation/evaluation in different production systems and agroecological conditions. Genome-wide linkage disequilibrium (LD) analyses revealed a fast LD-decay, on average at about 2.54 kbp, in the overall population with the LD-decay slower in the ILRI material compared to the EMBRAPA collection. This genotyping initiative generated high-density markers with a reasonable distribution across the genome. The diversity analysis revealed the existence of a substantial amount of variation, particularly in the ILRI collection and identified some unique materials from the EMBRAPA collection, demonstrating the suitability of the overall population for further genetic and marker-trait association studies.

Keywords: DArTseq, diversity analysis, elephant grass, forage, genebank, linkage disequilibrium

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Insights into the *Batatas* Complex: A Crossing Study and its Significance for Breeding

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Sweetpotato crop wild relatives (*Ipomoea* series *Batatas* (Choisy) D.F. Austin) are an untapped and potentially valuable source of genetic diversity for crop improvement. However, the use of wild relatives in sweetpotato breeding remains largely unexplored as obstacles specific to this group must be overcome to fully unleash the resources provided by the sweetpotato crop wild relatives (SP CWR). These difficulties include, for example, unclear species delimitation, lack of diagnostic characters enabling differentiation among taxa, different ploidy levels and unknown levels of cross compatibility. Thus, the objective of this study was to test the compatibility of SWP CWR through a systematic interspecific and intraspecific crossing study to provide information critical for the design of a pre-breeding approach. The crossing study included 46 accessions from eight out of 14 CWR species of the series *Batatas*: *I. cordatotriloba*, *I. cynanchifolia*, *I. grandifolia*, *I. leucantha*, *I. ramosissima*, *I. splendor-sylvae*, *I. trifida*, and *I. triloba*. The crossing design was a full diallel with 2,070 possible cross combinations and a target of 20 crosses completed per cross combination. Three crossing groups with high levels of interfertility (>40 %) within the diallel were identified that correspond to three distinct syngameons. Crossing group 1 (CG1, 24 accessions) contained *I. cordatotriloba*, *I. cynanchifolia*, *I. grandifolia*, *I. leucantha* and *I. triloba* while CG2 (12 accessions) included *I. trifida* and one *I. ramosissima* accession. CG3 encompassed four *I. ramosissima* accessions. Crosses between accessions of CG1 and CG3 exhibited zero to low levels (<27 %) of interfertility but no absolute barriers to reproduction. In contrast, accessions from CG2 did not form fertile offsprings with CG3 indicating reproductive isolation. Accessions from CG1 (self-compatible species) as females crossed at zero to low levels with accessions from CG2 (self-incompatible species) as males, but the reverse shows no interfertility. This distinction provides us with a roadmap for future pre-breeding approaches. *I. trifida* accessions from CG2 (as males) may serve as bridge species to introgress desired traits from CG1 (as females) into the sweetpotato gene pool.

Keywords: Cross compatibility, crossing barriers, *Ipomoea*, pre-breeding, sweetpotato crop wild relatives

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Evaluation of Agronomic Traits Variation in White Yam (*Dioscorea rotundata*)

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Yams (*Dioscorea* spp.) are grown globally in Africa, Asia, Latin America, Caribbean and Oceania. Especially in the West African, there is a great demand for yam as staple food as well as a cash crop with increasing population. Among the 20 or more species of yam, white yam (*D. rotundata*) is the most important species as food material in West Africa. The growth characteristic of white yam such as large plant size and the long growing period makes it difficult to conduct field experiments and evaluations of the agronomic traits. Moreover, systematic breeding has hardly been carried out so far due to lack of plant physiological information. Although the genetic resource material held by IITA may include individuals with high breeding value, the diversity of their agronomic traits has not been clarified. Therefore, to obtain basic information for promoting white yam breeding, the evaluation of agricultural traits in the genetic resource material was conducted. The experiment was conducted at 2017 cropping season (May to Dec) in IITA Ibadan, Nigeria. Thirty genotypes of white yam were selected from IITA genetic resource material and used in this experiment. Destructive sampling was carried out to understand the tuber index (tuber weight / total plant weight) at early September. Growth period was calculated from date of sprouting to date of aerial part 100 % senescence. Tubers were harvested in December. The varietal difference between genotypes was clearly observed in agronomic traits. The genotypes with high tuber index in September tended to have a short growth period. The tuber yield was correlated with the aerial part biomass in September, suggesting that the biomass of the aerial part up to September are key traits to obtain a high tuber yield. From these results, it is expected to contribute to white yam breeding and development of improved varieties suitable for the region.

Keywords: Agronomic traits, varietal difference, yam

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Cassava Varietal Performance and Productivity Analysis under Subjective and Objective Measurements - A Case of Malawi

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Cassava is the second most important crop to maize in Malawi. Since 1995 per hectare yield of cassava has more than quadrupled and production has increased more than nine times between 1997 and 2007. This is mainly attributed to breeding and dissemination of improved varieties through collaborative programs between the government of Malawi and the International Institute of Tropical Agriculture (IITA). However, despite all the efforts put into breeding and dissemination of improved cassava varieties, several weaknesses in evaluating the performance of these crop technologies at plot level still persist. These include for instance high variability in on-farm yield, piece-meal harvesting, and varietal misidentification, implying that both adoption and impact estimates of improved cassava varieties cannot be trusted. Although studies have investigated the effect of systematic measurement errors in agricultural surveys, only few have assessed their effect on varietal performance and productivity analysis. The current study therefore investigates the effect of measurement errors on varietal performance and productivity analysis. The study used data from methodological experiment on cassava varietal identification and productivity measurement (CVIP 2015) collected over 1129 households in five districts in Malawi. Using DNA fingerprinting and crop-cutting as benchmarks, descriptive statistics showed that farmer estimates were more volatile in estimating yield on selected varieties compared to crop-cutting. The latter, on the other side, over-estimated yield by 30 percentage point on average. Econometric estimations showed under crop-cutting that though cassava has always been advertised as a woman's crop, female-headed households were still less efficient as compared to those of their male counterparts. Furthermore, while adoption appeared to have significant effect on technical efficiency under farmer estimates, crop-cutting showed on the other side that this variable was not of crucial importance on farmers' technical efficiency. Study findings support therefore investment in advanced quality data collection through more reliable methods such that yield can be tracked to specific variety; but also the role played by socioeconomic factors, especially gender in adoption and impact of food security crops. Hence, periodic dissemination of planting materials for resource-constrained groups such as women as well as training of extension workers for better varietal identification are mainly recommended.

Keywords: Measurements, productivity analysis, varietal performance

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Phenotypic Diversity of Rice Landraces Collected from Ayeyarwady Region, Myanmar Using Agro-Morphological Characterisation

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An investigation was conducted to determine the agro-morphological characterisation and relationship between rice accessions collected from the Ayeyarwady region for their utilisation in breeding programs. The use of agro-morphological traits, both qualitative and quantitative, is the most common and traditional approach utilised to estimate relationships between genotypes. In this study, 117 accessions were characterised for 13 qualitative and 15 quantitative traits as per IRRI rice descriptors. Qualitative traits were analysed using Shannon diversity and cluster analysis by NTSYS, whereas quantitative characters were subjected to principal component analysis (PCA) and coefficient matrix. The standardised Shannon-Weaver diversity index ranged from 0.41 (least polymorphic) for sterile lemma colour to 0.84 (highly polymorphic) for amylose content with an average of 0.7. Cluster analysis separated the different varieties into various groups. Truncating the tree at the Euclidean distance of 1.18 resulted in 15 clusters. In the truncated tree, 3 clusters had single accession, 5 clusters had two to three accessions, 6 clusters had five to eighteen accessions and the largest cluster had 44 accessions. Four accessions (TLNKYAUUK, MSEIK, MSWE and KYTUN) clustered together in the genetic distances (0.00) due to their similar qualitative traits. For analysis of 15 quantitative traits, the coefficient of variation was more than 10 % for most of the characters, the highest one being the number of panicles per plant (24.54 %). Correlation analyses among quantitative traits showed a strong positive correlation in some traits such as long and short sterile lemmas, grain length and length-width ratio, harvest index and yield. The principal coordinate analysis showed similar groupings as in the cluster analysis. PCA has revealed six major components (Eigenvalue > 1), which altogether explained 80.4 % of the total variation. Component loadings for each principal component showed quantitative traits, such as grain width, yield and harvest index that were among the phenotypic traits contributing positive projections in three principal components that explained 54 % of total variation in the characterised rice accessions. The present study indicated that diversity in agro-morphological traits were useful for preliminary evaluation for crop improvement programme and can be used for assessing genetic distance among morphologically distinguishable rice landraces.

Keywords: Agro-morphological characterisation, landraces, Myanmar, *Oryza sativa*

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Genetic Diversity of Native Guatemalan Avocado Using SSR Molecular Markers

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Avocado is one of the most widely consumed crops worldwide and originated in the Sierra Nevada region in California eight to five million years ago. In Guatemala, a high genetic diversity has been reported by morphological characterisations, but due the cross-pollination and interracial hybridisations, these characterisations present complications and it is not possible to detail the total genetic richness. Molecular markers are a useful tool for this type of studies because they are free of environmental effects and focus on differences at the DNA level. The main objective of this study was to analyse the genetic diversity of 189 materials of native Guatemalan avocado collected in seven populations located in eight departments of the country, using 11 SSR molecular marker. A total number of 262 polymorphic alleles were detected with a mean number of 10.701 per population. Among population, the expected heterozygosity varied from 0.738 to 0.837. The analysis of molecular variance (AMOVA) showed that only 2 % genetic variation existed among population, while 65 % existed within individuals and 33 % existed among individuals. Moderate differentiations among the analysed populations were indicated by F_{st} index 0.018. Structure analysis suggested two and four cluster for the whole avocado materials. The lack of population structure is attributed to the process of selection, the system of cross-pollination, the exchange of seeds and the process of domestication to which the avocado is still subject. We therefore suggest the protection of the phylogenetic resource, as well as a complementary agromorphological characterisation, to establish an adequate strategy of exploitation through plant breeding programs.

Keywords: Avocado, genetic diversity, Guatemala, SSR

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***In vitro* Conservation and Recovery of *Ullucus tuberosus* (Loz.) after Reduced Growth of Microshoots**

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In vitro conservation by the use of reduced growth is considered to be a reliable biotechnological tool for medium-term conservation of plant germplasm while ensuring its immediate availability. In the present study, we assessed reduced growth condition using five culture media supplements, a cultivation temperature of 4°C and a 24 h *in vitro* growth in complete darkness, to establish a simple and reliable *in vitro* conservation protocol for ulluco (*Ullucus tuberosus*). Ulluco is an Andean tuberous crop rich in carbohydrates and vitamin C and it represents a staple crop for local people. For this experiment, individual nodal segments of ulluco were precultured for 28 days on half-strength Murashige and Skoog (MS) medium maintained in a culture room under a 16/8 h light/dark regime at 17°C, and at a photosynthetic photon flux density of 35 $\mu\text{mol m}^{-2} \text{s}^{-1}$ provided by cool-white fluorescent tubes. They were then transferred to half-strength MS medium supplemented with mannitol (10–30 g l⁻¹), sorbitol (10–30 g l⁻¹), sucrose (10–120 g l⁻¹), chlorocholinchlorid (CCC; 300–700 mg l⁻¹) or abscisic acid (ABA; 1–3 mg l⁻¹) and were placed in a cultivation temperature of 4 °C and a 24 h dark conditions for 24 months. Based on survival percentage and number and size of MTs, three superior treatments were selected for further experiment on microtuber germination: mannitol (20 g l⁻¹), sorbitol (30 g l⁻¹) and sucrose (90 g l⁻¹). Three regrowth media were tested: MS, half-strength MS and MS supplemented with 0.5 mg l⁻¹ GA3. After 3-months survival, MT germination and morphological characteristics were evaluated. Results showed that MS cultivation medium supplemented with GA3 and MTs originated from conservation medium supplemented with 90 g l⁻¹ sucrose showed the fastest regrowth and provided overall superior characteristics over plants from other conservation treatments and tested regrowth media. The protocol optimised in this study provides minimal labour and efficient method of ulluco conservation for 24 months.

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Keywords: Gibberellic acid, *in vitro* conservation, microtubers, sucrose, ulluco

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Survival Is Insufficient: A Cryopreservation Case Study on Cassava

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Food security is one of the sustainable development goals of the United Nations. Most of the regions that are affected by this insecurity are areas with infertile or dry soils, often located in the tropics. An essential crop in such environments that provides food security is cassava, an important source of carbohydrates and the third most important crop in the tropics. Even though there is only one cassava species, there are plenty of varieties, each with its own characteristics, allowing the species to survive in many different areas. Having access to such a diversity within the species is important for farmers since it allows them to adapt to different situations.

The cassava diversity can be kept in field and *in vitro* genebanks but the ultimate way of preserving cassava for the long term is using cryopreservation. In these conditions plant tissues are cooled to the temperature of liquid nitrogen (-196°C). At this temperature all biological and chemical processes come to a halt. However for cassava this cryopreservation protocol is not yet optimised. In this study, different parameters during the cryopreservation protocol were varied, such as the application of a sucrose preculture, different loading solutions and the use of apical versus axillar meristems and this on three different cassava varieties. One month after recovering from the liquid nitrogen exposure, this resulted in survival rates of up to 91 % for some cultivars. Under survival we understand that new green leaves were formed. However after this initial growth, the shoots completely stopped growing and this for both control and cryopreserved meristems, suggesting that the storage in liquid nitrogen is not the main bottleneck. Regeneration towards normal rooted plants is thus the next hurdle to overcome, before we can speak about a cryopreservation protocol that is applicable to an *in vitro* collection.

Keywords: Cassava, cryopreservation, genebanks, *in vitro* culture

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