

NUS 2013

3rd International Conference on Neglected and Underutilized Species: for a Food-Secure Africa
Accra, Ghana, 25-27 September 2013

Book of Abstracts

Editors: Richard Hall, Per Rudebjer and Stefano Padulosi



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Cover photo: Girl picking millet in the village of Dokoro, Uganda, with her three-month old baby on her back. Caroline Penn / Panos

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Foreword

We are pleased to present in this book all the abstracts which are being presented orally or as posters at the 3rd International Conference on Neglected and Underutilized Species (NUS): for a Food-Secure Africa, Accra, Ghana, 25-27 September 2013. This conference represents the culmination of a three-year project funded by the ACP-EU Science and Technology Programme (*“Building human and institutional capacity for enhancing the conservation and use of neglected and underutilized species of crops in West Africa, and Eastern and Southern Africa”*). The project was implemented by six African and two European organizations¹ and comprised regional meetings to identify priority underutilized crops with potential, and subsequently capacity-enhancing workshops for African researchers focusing on project proposal preparation, scientific communication, nutrition, experimental design and methodologies and value chains which themselves focused on the identified priority crops in each region. The Conference, through highlighting priorities and needs of researchers identified during the project and through showcasing research representative of underutilized crops in Africa and beyond, will take stock and make policy recommendations as to the way forward in order that underutilized crops can truly deliver the benefits to society in the form of the promised potential valuable sustainable outputs.

The large number of abstracts received (438) does indeed reflect a profound and growing interest in the use enhancement of underutilized crops for sustainable food security, climate change adaptation, and for medicinal and other purposes. The message that the world is over-dependent on a small number of homogeneous varieties of a few major crops (e.g., rice, wheat, maize and potato), with their concomitant potential vulnerabilities to disease, pests and global change, seems to be getting across to scientists, particularly in Africa, and in turn, policy makers.

This Conference has been preceded by two other international events focusing on NUS which were held in 2008 and in 2011 in Arusha (Tanzania) and Kuala

¹ Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), Uganda). International Foundation for Science (IFS), Sweden; Bioversity International, Italy; African Network for Agriculture, Agroforestry and Natural Resources Education (ANAFE), Kenya; Institut de Recherche et de Développement sur la Biodiversité des Plantes Cultivées, Aromatiques et Médicinales (IRDCAM), Benin; Plant Genetic Resources Research Institute (PGRRI), Ghana; University of Nairobi, Kenya; and University of Malawi, Malawi.

Lumpur (Malaysia), respectively. These events, which were very well attended by the scientific community, provided an important contribution in advancing the knowledge on challenges, needs and opportunities regarding the sustainable conservation and use of NUS in Africa and elsewhere around the world. Seizing the window of opportunity offered by the above-mentioned ACP-EU project, this third gathering aims to continue the dialogue among NUS experts, which is so critical for moving forward the Agenda on these crops. The special emphasis on capacity building for researchers at this third rendezvous is an element of novelty which responds to the strong request voiced by national programmes, especially of African countries and consistent with a key strategic element identified in the Cordoba Declaration² on NUS emanating from an important meeting held in Spain in December 2012.

The organizers of the Conference express their gratitude to all those who have worked hard to make this event possible. We are particularly grateful to The Council for Scientific and Industrial Research (CSIR) of Ghana for having enthusiastically agreed to host the Conference and oversee the local organization of the event. Our profound gratitude goes also to the EU-ACP Science and Technology Programme for supporting our NUS project and to the other donors who have kindly mobilized additional financial resources for securing the realization of this meeting (their full list is provided in the acknowledgement section below).

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² Full text of the Declaration available at <http://bit.ly/11WFEJx>

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Conference committees

We express our gratitude to the members of the International Organizing Committee, the Local Organizing Committee and the Scientific Committee who have worked hard to make this Conference possible.

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Part 1

Oral presentations

Part 1. Oral Presentations

Theme 1: Resilience of agricultural and livelihood systems

This theme addresses the role of neglected and underutilized species in resilient food production systems in Africa and the importance of diversification for food security in sub-Saharan Africa. Abstracts under this theme review practices and lessons learnt on how farmers deploy NUS in their farming systems for food production, and for reducing biotic and abiotic risks, including those related to climate change. Many NUS species are known to be of very high nutritional value; their strategic role for nutrition and health is also covered in this section.

Abstracts under Theme 1 fall into five sub-themes:

- 1.1 Agronomy
- 1.2 Conservation
- 1.3 Global and climate change
- 1.4 Utilization, processing and post-harvest
- 1.5 NUS for nutrition and health

1.1 Agronomy

Response of indigenous fruit trees under domestication in West and Central Africa to grafting

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Indigenous fruit trees of high nutritive, medicinal, cosmetic, economic and environmental values are currently under domestication as new 'cash' crops to farmers in most countries of West and Central Africa. Domestication techniques such as vegetative propagation (rooting of cuttings, air-layering, grafting) are being developed aiming to reduce the long juvenile phase to fruiting while maintaining trueness in the transfer of desirable traits (fruit, seed, bark etc.) over generations. Vegetative propagation studies were carried out to assess the amenability of grafting in the improvement of five priority indigenous fruit trees of West and Central Africa (*Irvingia gabonensis*, *Garcinia kola*, *Cola nitida*, *Ricnodendron heudelotii* and *Monodora myristica*). Five month-old rootstocks of these indigenous fruit trees under 60% shade cloth were grafted using side tongue, top cleft, side veneer, and whip-and-tongue grafting methods. It was observed that the combined effect of species and grafting methods influenced significantly ($p=0.05$) graft success nine weeks after grafting. *Garcinia kola* displayed the highest graft success rate irrespective of grafting method, ($90 \pm 5.47\%$ - $96.67 \pm 3.26\%$) followed by *Monodora myristica* ($53.33 \pm 9.10\%$), *Ricnodendron heudelotii* ($50.0 \pm 9.12\%$), *Irvingia gabonensis* ($43.33 \pm 9.04\%$) (top cleft method respectively) and *Cola nitida* ($38.89 \pm 11.49\%$) (side tongue). Rootstock origin in terms of species significantly ($P=0.001$) influenced graft success using *I. gabonensis* scions, with *I. wombolu* rootstocks registering higher ($45.5 \pm 7.75\%$) graft success compared to *I. gabonensis* and *I. grandifolia*. These results indicate the potentials of grafting in the improvement of these priority indigenous fruit trees species. However, in-depth studies are recommended for each species to optimise conditions for increased graft successes.

Keywords: domestication, grafting methods, rootstocks, vegetative propagation,

Ecological and human impacts on stand density and distribution of tamarind (*Tamarindus indica* L.) in Senegal

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Indigenous fruit tree species such as tamarind (*Tamarindus indica* L.) in sub-Saharan Africa traditionally act to build resilience into the farming system in terms of food security, income generation and ecosystem stability. Therefore, increasing our knowledge on their ecology and distribution is a priority. Tamarind is mainly grown for the fruits but is also a valuable timber species. The fruit pulp has a high content of vitamin B and is eaten fresh or made into jam, chutney, juice or sweets. Flowers, leaves and seeds are also edible and used in a variety of dishes. The main objective of this study is to evaluate actual density of tamarind in Senegal and the climate change effects on its distribution for better conservation strategies. The distribution and density of Tamarind around villages were recorded and modelled in different agro-ecological zones in Senegal using a transect method and under current and future climates. Distribution under two future climate scenarios was modelled using four climate models and three time slices (2020, 2050 and 2080). Results show a decreasing gradient in tree density (from 7 to 1 trees/km²) from the Sudano agro-ecological zone (in the south) to the Sahel (in the north). Future climate predictions show that although tamarind distribution will increase in the north-west and south of the country in 2020, by 2050, the area identified as suitable for its growth will be greatly reduced. Areas in the north-west basin appear to be important refugia for the species under future climate conditions. However, the density around villages in this area was found to be relatively low indicating that this could lead to problems of poor gene flow and inbreeding depression. This region should therefore be highlighted as important for conservative management and protection strategies of tamarind in this region.

Keywords: Sahel, modelling, ecology, MaxEnt Senegal, climate change

Local uses of indigenous fruit trees in the Lake Victoria Basin, Rwanda

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Rural communities within the Lake Victoria Basin are subsistent in nature and also traditionally dependent on indigenous fruit trees to partially meet their nutritional, income and health requirements. Depending on the way the rural communities consider indigenous fruit trees and the information they have, the interaction and the traditional use of indigenous fruit trees is specific and valued by some classes of people. The present study was carried out in districts of Bugesera, Kirehe, Musanze and Nyamagabe in Rwanda with the aim of identifying the preferred indigenous fruit trees and assessing their uses. A total of 816 farmers who may benefit from IFTs were interviewed during data collection. Focus group discussions were also conducted in two cells in each district to collect data. Indigenous fruit trees such as *Garcinia buchanani*, *Ximenia caffra*, *Pappea capensis*, *Strychnos* sp., *P. curatellifolia*, *Lannea schimperi*, *Carica cundinamarcensis* and *Myrianthus holstii* were reported as the most preferred indigenous fruit trees in the selected areas. These wild plant species are sources of food, medicine and income for communities. Medicine is traditionally prepared mostly by the decoction of leaves, bark and roots. Syrup was also extracted from different parts of fruit trees to treat a number of ailments. Infusion is also another way of preparing medicine. Indigenous fruit trees therefore play an important role in communities' livelihoods.

Keywords: indigenous fruit trees, local knowledge, food security, livelihood

Local perceptions and endogenous technologies of *Carapa procera* oil production in Mali

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Carapa procera is a wild oil tree species traditionally exploited for its nuts used to produce oil. This oil is highly sought for its therapeutic, cosmetic, insecticide and repellent properties. The purpose of this work is to contribute to the understanding of local knowledge of *Carapa procera* oil production and local perceptions related thereto. The method used is based on interviews about different areas of production and testing of oil production based on traditional processes practiced by the producers. Different methods of conservation of nuts and oil extraction processes are used by women, the main actors of oil extraction and processing. The average extraction efficiency obtained of the nuts was $23 \pm 1.04\%$. Despite their traditional expertise, difficulties related to technology (lack of adequate machinery for mining), oil marketing (difficulties of access to a profitable market) and decrease of *Carapa* species limit the full development of activities. Several local perceptions related to exploitation and oil production from *Carapa procera* were reported by producers. However, *Carapa procera* oil production is an activity that generates significant income for producers and contributes to improving the living conditions of women. In this perspective, it is necessary to undertake options to improve the traditional oil production processes and value chain, as has been done for shea butter.

Keywords: *Carapa procera* oil, local process, efficiency, socio-cultural considerations, Mali

Enhancing the resilience of livelihoods of small millet farmers through participatory varietal selection in India

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Small millets are nutritious but underutilized crops that are grown in heterogeneous rain-fed environments ranging from hills to coastal agro-ecosystems in India. In the last two decades, these rain-fed ecosystems have been affected by various climate change-related issues, especially the rainfall pattern. These changes vary from place to place. So there is a need for varietal selection for each micro agro-ecosystem, instead of the existing and commonly followed geographically centralised breeding, with the participation of farmers to identify suitable varieties. With this objective, Participatory Varietal Selection (PVS) is practised in five sites in India under a research project 'Revalorizing Small millets in Rain-fed Regions of South Asia'. It is a project supported by CIFSRE, by IDRC and CIDA, Canada. The methodology adopted comprises understanding the varietal preferences of farmers, short-listing the traditional as well as improved varieties suitable for the changed rainfall regimes, on-farm evaluation through mother and baby trials, and promotion of identified suitable varieties through community-based channels.

In the two cycles of PVS trials, 60 local varieties, 53 released varieties and 4 pre-release varieties of small millets were tested with the involvement of 578 men and 333 women farmers. Based on farmers' preferences and performance in the trials, 20 potential varieties were identified. The results of these studies highlighted the importance of farmers' participation in the varietal selection process, as only they know well the change in rainfall at the micro level. In many sites, a few traditional varieties from the nearby area were also identified, along with the most promising improved varieties, as they have already proven their performance under similar agro-ecosystems. It is expected that this project will result in a demonstration of scaled-up PVS for enhancing resilience and will create a case for supporting potential traditional varieties under government crop support systems.

Keywords: varietal diversity, traditional varieties, preference analysis, PVS, small millets

Daylength effects on growth and seed production efficiency in Bambara groundnut (*Vigna subterranea* L.)

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Daylength affects the reproduction of many crop species that grow away from the equator. Because daylength cannot be regulated in field conditions, it is important that crop genotypes have appropriately matched photoperiod requirements to ensure reproductive success at different latitudes and in different growing seasons. This is an issue with Bambara groundnut (*Vigna subterranea* L.), an underutilized African legume rich in protein which grows on marginal soils. In this species, whilst incorrect daylength can delay flowering, it can completely prevent pod-filling. For smallholder and subsistence farmers, where the sowing date of the crop is often determined by the timing of the rains, matching photoperiod requirement to daylength is important for reproductive success. The objective of this work was to determine photoperiod effects on reproductive efficiency and to develop photoperiodic ideotypes for different production systems. Plants grown as crop stands in three climate-controlled glasshouses with 12/14/16 h of daylength were examined for photoperiodic requirements for pod-filling and yield in five landraces. Three photoperiodic types have been identified: 1) qualitative short-day (Ankpa 4), 2) quantitative short-day (Getso, Gresik and LunT) and 3) quantitative long-day (IITA-686). Seed number doubled in 16h for IITA-686, but incomplete pod-filling (due to indeterminacy in 16h) led to an overall reduction in average seed weight. These results support the hypothesis that manipulating photoperiod sensitivity may be an avenue to increasing yield in Bambara groundnut. Parental genotypes derived from landraces which differ for photoperiod requirement have been crossed and a series of mapping populations created. Progress to alter photoperiod requirement for pod filling to stabilize yields and improve uptake of this underutilized crop will be presented.

Keywords: daylength requirement, photoperiod, Bambara groundnut, *Vigna subterranea*

Castor bean as a potential bio-energy crop: biodiversity in Egypt

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Energy is at the core of socio-economic development all over the world. Lack of access to reliable, modern and sustainable energy supplies is a major contribution to underdevelopment and poverty. Castor bean is an important non-edible oilseed crop widely cultivated in tropical, sub-tropical and temperate countries for its high economic value. This work aimed to study diversity and distribution of castor landraces in Egypt, to evaluate the potential possibility of using castor as a bio-energy crop. The castor seeds of four landraces (L1, L2, L3, and L4), were obtained from different locations in Egypt. The seeds were investigated for physical and chemical properties, and were planted at the research farm of the soils and water department, Nuclear Research Centre, Atomic Energy Authority, Egypt, during the 2011 and 2012 seasons. The morpho-agronomic properties were studied. Furthermore, the oil concentration, and fatty acid composition were also studied. The results indicated that: 1) there was a high diversity among the castor bean plants and some landraces could be used in breeding programs. 2) The landrace (L1) had greater plant height (320 cm), and recorded the highest main spike weight (50g) than the other landraces. 3) The second landrace (L2) recorded the highest fresh weight of leaves (17.54g), the tallest main spike (38.0 cm), the maximum capsules per plant (665.7), the highest number of capsules per spike (39), the highest number of seeds per spike (117), and the highest number of seeds per plant (1997). 4) The third landrace (L3) had the highest number of spikes per plant (31). 5) The fourth landrace (L4) produced the heavier grains (71g) followed by L2 (50g). However, the lowest 100 grain weight (18g) was observed in L3. 6) A big variation was found in oil percentage ranging from 39.6 to 59.5%. As regards fatty acids, slight variation was noted in ricinoleic acid, which is the major component of castor oil ranging from 83.65 to 90%. The landraces with a high seed yield, oil content and proper fatty acid composition will be further investigated for biodiesel production.

Keywords: biodiversity, castor bean, landraces, biodiesel, fatty acids

Yield response of selected taro (*Colocasia esculenta* L. Schott) landraces from South Africa to irrigated and rain-fed field conditions

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Taro (*Colocasia esculenta* L. Schott) is an important under-utilized crop in sub-Saharan Africa, owing to limited agronomic research. It is mainly cultivated by subsistence farmers, mostly women, using landraces of which little is known about their agronomy and drought tolerance. The aim of this study was to evaluate drought tolerance mechanisms of three taro landraces collected from Umbumbulu [(UM and Dumbe lomfula (DL)] and KwaNgwanase (KW) rural areas in KwaZulu-Natal under field conditions. Field trials were planted at Roodeplaat, Pretoria, in September 2010. The trial was laid out in a split-plot design arranged in a randomized complete block design, with irrigation (Irrigated vs. Rain-fed) as main plots and landraces (DL, KW and UM) as sub-plots and replicated three times. Soil water content was monitored weekly using the gravimetric sampling method. Emergence, plant height, leaf number, leaf area index, and stomatal conductance were determined weekly. Yield and yield components were determined at harvest. Emergence of taro landraces was slow and showed highly significant differences ($P < 0.001$) between landraces. Landrace DL did not form a good stand compared to KW and UM. Growth of taro landraces (plant height, leaf number and LAI) as well as stomatal conductance were all significantly ($P < 0.05$) lower under rain-fed than irrigated conditions. Results showed that, although not statistically significant, total biomass, harvest index, corm number and mass and final yield were lower under rain-fed compared to irrigated conditions. However, there were highly significant differences between landraces; DL failed to form any yield under both rain-fed and irrigated conditions while the UM landrace had higher yield than the KW landrace. Overall, the UM landrace showed better adaptation to limited water availability and exhibited drought avoidance and escape mechanisms.

Keywords: drought, taro landraces, yield

Agromorphological characterization of *Amaranthus* species in central Malawi

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Twenty-seven accessions of *Amaranthus* species from central Malawi were characterized using agro-morphological traits. A total of twenty-six descriptors, mainly defined by the International Plant Genetic Resources Institute (IPGRI) were used to describe stems, leaves, roots and the plant itself from December 2011 to April 2012. Qualitative descriptors included parameters such as growth habit, presence of spines in leaf axils, branching index, leaf shape, terminal inflorescence while the quantitative descriptors included plant height, growth habit, leaf number, seed yield, and number of spines. Means were separated using Tukey's Honest Significant Difference Test that grouped related accessions. The means were compared at ($P \leq 0.05$) using the Least Significant Difference (LSD). The analysis of variance (ANOVA) showed significant differences ($P \leq 0.05$) in all parameters that were studied with plant height, growth habit, leaf number, and seed yield being the most important parameters in delineating the uniqueness of the different accessions. A dendrogram gave a clear separation amongst the accessions into three main groups based on plant height, yield and growth habit. The highest yielding accessions were BV-BF-01 (*A. hypochondriacus*) and LL-BF-04 (Green Giant) for seed and leafy vegetables respectively. Leaf yield ranged between 6554 kg ha⁻¹ and 31599 kg ha⁻¹ while seed yield ranged between 450 kg ha⁻¹ and 3900 kg ha⁻¹. There is high diversity of *Amaranthus* species in Malawi and this represents a genetic resource for future conservation and breeding. This work is an important step in the conservation of *Amaranthus* species in the Central Region of Malawi, which show distinctive and interesting morphological characters such as prostrate versus erect growth, availability of axillary inflorescences and the varying lengths of inflorescences. The study also showed that very few farmers are involved in the formal cultivation of *Amaranthus* species due to stigmatization of the crop and a lack of agronomical practice.

Keywords: agro-morphology, *Amaranthus*, characterization, genetic diversity, plant descriptors

Why is Bambara groundnut able to grow and fix N₂ under contrasting soil conditions in different agro-ecologies?

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Bambara groundnut is an important African food legume with high nutritional value and with adaptation to varying environmentally stressful conditions. However, it is under-researched and under-utilized. Thus, there is little information on N₂ fixation in Bambara groundnut, rhizobial diversity and symbiotic efficacy of the bacterial symbionts nodulating this species. Very few studies have reported on the water-use efficiency of Bambara groundnut. This study therefore assessed symbiotic N nutrition in Bambara groundnut from farmers' fields, characterized bacterial isolates from root nodules, and measured the species' water-use efficiency in farmers' fields. The data revealed marked ($P \leq 0.05$) differences in plant dry matter yield, N concentration and content, $\delta^{15}\text{N}$, proportion of N derived from symbiotic fixation (%Ndfa), and actual amounts of N-fixed between and among materials surveyed in 26 farmers' fields. Bambara groundnut plants obtained 33 - 98% of their N nutrition from symbiotic fixation, and contributed 4 to 200 kg N fixed ha⁻¹. Plant density correlated positively with %N ($r = 0.31^{***}$), $\delta^{15}\text{N}$ ($r = 0.126^{***}$) and amount of N-fixed ($r = 0.15^*$), indicating that the high %Ndfa values obtained for Bambara groundnut and the low symbiotic N yield associated with some farms was due to low plant density rather than poor symbiotic functioning. Isolation and phenotypic characterization of root-nodule bacteria nodulating Bambara groundnut revealed diversity in colony growth rates (some were fast-, slow- and intermediate-growing). 16S rDNA gene sequencing showed that the microsymbionts nodulating Bambara groundnut belonged to four bacterial genera, namely, *Mesorhizobium*, *Rhizobium*, *Bradyrhizobium* and *Burkholderia*. The $\delta^{13}\text{C}$ values ranged from -28.01‰ to -26.20‰, which indicates differences in plant water-use efficiency on the different fields studied.

Keywords: Bambara groundnut, nitrogen fixation, rhizobial biodiversity, nutrient-poor soils, water-use efficiency

Exploring variation and trait relationships among selected finger millet [*Eleusine coracana* (L.) Gaertn.] accessions from Uganda

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Finger millet is a vital component in the farming systems of many parts of Uganda. Its use is however constrained due to limited research and blast disease. The objectives of the study were to assess the variability and performance of the different accessions for yield and reaction to blast disease, and investigate trait association among accessions to determine the genetic potential for future use in a breeding programme. Experiments were conducted using 100 accessions mainly landraces in a 10 × 10 lattice design replicated three times during the first rains of 2010 at two sites. Data were subjected to REML analysis, frequency distribution, correlation and path analyses. The results revealed high variability for traits considered in the study, although some traits also showed significant differences due to environment. The mean performance of 15 top yielding accessions at both sites ranged from 3.23 – 4.56 tons ha⁻¹. Seven of these accessions performed well at both sites. High resistance to leaf blast at both sites was recorded from three accessions while four accessions showed high resistance to ear blast. The distributions revealed the presence of accessions with desirable agronomic traits and levels of resistance to both leaf and ear blast disease. Correlation analysis revealed high positive association between grain yield ha⁻¹ with panicle width, finger number, productive tillers and grain weight per head, but highly negative with leaf blast incidence, ear blast incidence, ear blast severity and days to 50% flowering. The association analysis also indicated the importance of ear blast in yield reduction compared to leaf blast. Path analysis further revealed that in determining yield, the most important traits were grain weight per ear, tillering ability and reaction to ear blast disease. The following criteria could be used in indirect selection: days to 50% flowering, grain weight per head, finger number and threshing percentage.

Keywords: correlation, finger millet, landraces, path analysis, variation

Sustaining frafra potato, *Solenostemon rotundifolius* (Poir.), in the food chain: current opportunities in Ghana

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Frafra potato (*Solenostemon rotundifolius* (Poir.) is an underutilized crop species which is critical to improving food security in the Upper East Region of Ghana. The tubers are a delicacy, particularly for children, with a high marketing potential even compared with its counterpart, sweet potato. Crop improvement programmes for Frafra potato (FP) have been slow, farmers have continuously recycled the existing land races which are low yielding and produce numerous small-size tubers. This survey analyzed the current production practices, challenges and opportunities to improve FP production, processing and utilization in the Upper East Region. The study was carried out in June 2013 using a field survey, focus group discussions and key informant interviews. In all, information was captured from 250 respondents from 5 major producing districts. The survey showed that FP is produced under rain-fed agriculture by less than 30% of farmers, each producing a little less than ¼ hectare. In Bongo and Bolgatanga environs, the crop is cultivated by over 70% of households to supplement household food. The tubers are boiled and consumed in various forms as a main meal or snack, but the tubers become fibrous three months after harvest. Planting is done on ridges using single row spacing of 20 to 25cm between plants and 1m between ridges. All the group discussions suggest that optimum yield is obtained if planted on fertile loamy soils and sandy loam with high moisture holding capacity from late-May to mid-June. Production is primarily planned for domestic consumption, contributing about 20% of household food between September and December. Key problems identified were decreasing soil fertility, lack of improved varieties, labour-intensive production, operations and high post-harvest losses. Crop improvement programmes should target high-yielding cultivars which are large in size, easy to peel, white and pink flesh, biofortified with vitamins and prolonged shelf life. The active participation of research-policy-extension-and-private sector linkages is required to ameliorate the constraints of FP production in relation to up-scaling of improved technologies to increase production and utilization. Processing the tubers into stable preservable products and packaging should also be considered.

Keywords: *Solenostemon rotundifolius*, utilization, food security, underutilized crops, Ghana

Genetic improvement of winged bean (*Psophocarpus tetragonolobus*) for increased productivity and nutritional security

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Increased burden on major food crops urges new practices of agricultural diversification particularly using underutilized crops. Winged bean (*Psophocarpus tetragonolobus*) is an underutilized legume cultivated mainly in tropical countries in Asia and the Pacific. It is a multipurpose pulse, vegetable and root tuber crop and cultivated either as a cover crop for soil management or as a single crop. It has been called the 'future soybean' due to its high seed protein content. However, winged bean remains a crop yet to fulfill its potential. In the present study, the phenotypic traits of 24 contrasting winged bean accessions were evaluated. Morpho-physiological characterization showed significant variations ($P < 0.01$) within and among accessions suggesting improvement is possible through selection. The high yield/total weight ratio showed agronomic potential of some genotypes (e.g. line 319) and could form a basis for selection of parents for future breeding programmes. A dendrogram generated through *GenStat 15th Edition* gave an overview of the clustering pattern of accessions with respect to the assessed morpho-physiological characters. Additionally, a paired-end Mi-Seq sequencing of barcoded libraries for leaf, root and reproductive tissues (based on the pooled-RNA of six local accessions) has been conducted in order to generate a high coverage sequence assembly. Genic molecular markers will be dissected from the assembly for genetic diversity analysis. In conjunction with the morpho-physiological studies, this study seeks to dissect molecular information that gives novel phenotypic characteristics. The outcomes will greatly enhance winged bean breeding programmes for increased productivity and nutritional security.

Keywords: winged bean, *Psophocarpus tetragonolobus*, underutilized, morpho-physiological characters, dendrogram

Agronomic diagnosis on farmers' fields and effects of harvest date on fonio millet (*Digitaria exilis* Stapf) in south-eastern Senegal

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Fonio millet (*Digitaria exilis*) is a tropical cereal crop grown in Casamance and Senegal Oriental, two agro-ecological zones located in south and south-eastern Senegal, respectively. Research activities have been implemented in the production areas and at research stations in order to fill the knowledge gaps and improve the cultivation techniques. Firstly, a field survey was conducted in 2009 with 282 randomly selected farmers who used to crop fonio in their lands. Secondly, a trial on harvest date has been carried out during the rainy seasons 2010 and 2011, in Bandafassi and Sinthiou Maleme, respectively. The field diagnosis shows that fonio millet is cultivated on sandy soils or low fertility soils. In addition, around 80% of farmer fields are less than 0.5 hectare and the preceding crops are generally peanuts. Farmers use low-yielding landraces with low inputs. The seed are broadcast and crop husbandry is totally manual. The grain yields are variable and lower than 500 kg/ha. The grain losses become higher when harvest occurs too late. In order to improve grain yields by limiting yield-related losses, successive harvesting times were compared in 2010 at Bandafassi and in 2011 at Sinthiou Maleme. The results show no statistical effect of delayed harvest dates on aerial dry biomass and grain size. However, significant reductions were recorded in grain yield at both locations with successive harvest dates. The maximum grain yields were recorded when fonio straws were harvested between 90 and 97 days after the planting date. When fonio straws are mowed before 83 days after sowing or more than 111 days after sowing, the grain yields were reduced by 74% and 34%, respectively, in comparison to the optimal harvest period. Regarding these findings, farmers should harvest fonio straws at 1-2 weeks after plant maturity for fonio landraces with maturity ranging between 75-90 days.

Keywords: fonio, *Digitaria exilis*, harvest, dry matter, yield, Senegal.

1.2 Conservation

How far do home gardens conserve threatened underutilized species and crop wild relatives in Benin?

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Despite the growing literature supporting the importance of home gardens as biodiversity hotspots, our knowledge of patterns of their contribution to conservation of underutilized species and Crop Wild Relatives (CWR) in relation to climate and culture in Africa is limited. This investigation was conducted across three climatic zones to assess the floristic diversity of home gardens and the extent to which they contribute to conservation of threatened underutilized species and CWR. Overall, 240 home gardens were sampled and inventoried. The ecological importance of recorded species was assessed in each climatic zone using the importance value index (IVI). A cluster analysis was performed to group the species according to their IVI values and a principal component analysis helped to identify the most important species. Two hundred and eighty five species were inventoried in the home gardens throughout the three climatic zones of Benin. Among them, 20 crop wild relatives and 11 threatened species (7 vulnerable, 3 endangered and 1 extinct in the wild) were identified. Home garden species' diversity declined from the drier to the wetter zone but was highest in the transition zone. The most important home gardens species in the Sudanian, the Sudano-Guinean and the Guineo-Congolese zones were respectively: *Abelmoschus esculentus* and *Hibiscus asper*; *Solanum lycopersicum*; *Ipomoea aquatica* and *Senna occidentalis*. Thorough research on socio-economic factors supporting choice of species may help to assess home gardens' effectiveness in biodiversity conservation.

Keywords: underutilized species, conservation status, home gardens, importance value index, West Africa

National inventory and prioritization of crop wild relatives: case study for Benin

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Species prioritization is a crucial step in any development of conservation strategy, especially for crop wild relatives (CWR), since financial resources are generally limited. This study aimed to assess the biodiversity of crop wild relatives in Benin and identify priority species for active conservation. Data were collected through literature reviews to establish an exhaustive list of CWR in Benin. Eight prioritization criteria and different prioritization systems were used. The top 50 species obtained by each of these methods were identified and the final top CWR were shortlisted as those occurring as priority in all the methods used (point scoring procedure, point scoring procedure with weighting, compound ranking system and binomial ranking system) the eight criteria are: native status, economic value, ethnobotanical value, global distribution, national distribution, *in situ* and *ex situ* conservation status, legislation and threat assessment. A total of 266 plant species belonging to 65 genera and 36 families was identified. The most represented were: Cyperaceae (12.50%), Leguminosae-Papilionoideae (11.87%), Convolvulaceae (11.25%), Poaceae (10.31%), Asteraceae (7.81%), Solanaceae (6.87%) and Dioscoreaceae (5.31%). Among the 20 species of highest priority for conservation, *Manihot glaziovii* Müll.Arg. and *Piper guineense* Schumach. et Thonn., appeared as the most represented species on top of the list.

Keywords: biodiversity, conservation, crop wild relatives, threat, West Africa.

Ethnobotanic study and agro-morphological evaluation of Kersting's groundnut (*Macrotyloma geocarpum* Harms) varieties of Benin

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Kersting's groundnut (*Macrotyloma geocarpum* Harms - local name: "Doyi") is a grain legume with high nutritional and economic value widely consumed in Benin. To document indigenous knowledge on production, diversity and use of this species, 30 villages in the south and centre of Benin were surveyed. In each village, 10 to 15 households (374 farmers in total) were randomly selected and interviewed using participatory research appraisal tools and techniques. The study revealed that the production of Kersting's groundnut is particularly concentrated in the departments of Zou and Collines, but is fast declining. Ten reasons were identified explaining the decrease in its production, the most important being high cost of production (40.7% of responses), susceptibility of local varieties to high soil moisture (25.6% of responses) and complexity of cultural practices (25.2% of responses). Only three local varieties exist, and differ by seed colour (white, red and black). The white variety was the most widely cultivated because it is the most favoured for consumption. Gender role analysis indicated women are more involved in *M. geocarpum* production. Phenotypical analysis of the different accessions revealed only three groups which differed in plant diameter, days to 50% flowering and qualitative traits. Agronomic evaluation indicated a significant difference between grain yields of the three groups of varieties with average yields of 1062±93 kg/ha, 1197±77 kg/ha and 1548±102 kg/ha for the white, red and black seed varieties, respectively. A minimum of two weedings was optimal. A difference of approximately 167 kg/ha was observed between grain yields for two and three weedings but was not statistically significant. To improve yields, Kersting's groundnut fields should be weeded at least twice. Results from this study will help to define appropriate conservation strategies and also to implement adequate breeding programmes to improve and promote local varieties.

Keywords: Kersting's groundnut, Benin, varietal diversity, agro-morphological evaluation

Morphological and use-value related management of enset (*Ensete ventricosum* (Welw.) Cheesman) diversity and distribution in the Southern Nation Nationalities and Peoples Regional State: perspectives for on-farm conservation of crop genetic resources

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Enset, (*Ensete ventricosum* (Welw.) Cheesman) is a crop that provides food security for more than 20% of Ethiopia's population. The objective of this work was to assess the importance of morphological and use-value-related characterization of enset diversity and distribution management. A total of 280 farm households in seven zones was surveyed using individual household interviews. The frequency distribution of phenotypic similarity and other attributes showed the presence of some variation among enset clones. The observed traits showed low to high levels of diversity among enset clones with a Shannon-Weaver diversity index (H') value of 0.154 to 0.827 for bulla (extracted starch) quality and midrib colour, respectively. Kocho (fermented starch) yield was significantly correlated with bulla quality and plant vigour. Based on their morphological and use-value a total of 218 enset clones was recorded in the surveyed areas. The number of clones maintained on individual farms ranged from 2 to 26 (mean of 8.9 ± 0.94). Hadiya, with 59 clones, had the highest richness and Sidama with 30 clones had the lowest richness, mean richness being 39.4 ± 10.1 clones per zone. Clone abundance was the highest at Sidama (12.8) and the lowest for Gamo Gofa (8.5). Mean abundance was 9.64 ± 2.05 farms per clone. Sorenson's similarity index has shown that Wolaita, Dawro and Gamo Gofa shared many clones between themselves and were therefore more similar. Kembata and Hadiya also shared some clones. Exchange of clones seems to be mainly between adjacent zones. Knowledge of farmers' practices is currently used to validate agronomic innovations and inform the setting up of a network of genotype collections managed by farmers. Diversifying selection, and back-up *ex situ* conservations are key mechanisms responsible for the high diversity observed. Strategies of conservation of genetic resources should take these dynamic processes into account.

Keywords: enset, indigenous classification, management, morphology, use-value

1.3 Global and climate change

Impact of climate change on the geographical areas suitable for cultivation and conservation of neglected underutilized species: the case of the tamarind tree in Benin

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Climate change may limit integration of neglected underutilized Species (NUS) into formal cropping systems for increasing rural household revenues in Africa. The present study analysed the potential impact of climate change on the geographical areas suitable for tamarind (*Tamarindus indica* L.), an economically important NUS. Geo-referenced data on current locations of the species were collected and combined with bioclimatic data derived from the Worldclim data base and soil types data. The Maximum Entropy Modelling principle (MaxEnt) was used in combination with GIS to forecast current and future (Horizon 2050) suitable habitats for species cultivation and conservation. Three different climate models were used for future predictions (the CCCMA, HadCM3 and CSIRO models). Under current conditions, 65% of the national area and 87% of the national protected areas network were found to be highly suitable for local tamarind ecotypes cultivation and conservation respectively. Rainfall increase (CCCMA and HadCM3 models) could convert the zones currently highly suitable (semi-arid and sub-humid dry) into poorly suitable areas by 2050. Precipitation decline (CSIRO model) could also convert the zones currently poorly suitable (sub-humid/humid) into highly suitable zones. In the event of the climate becoming more arid (CSIRO model), cultivation and conservation of tamarind may be possible all over Benin and may further benefit from introduction of ecotypes from more arid lands. As the predictive capacity of climate models improves, this kind of study better informs decision-making for future optimal use of NUS.

Keywords: *Tamarindus indica*, adaptation, diversification, climate change, MaxEnt modelling

Variation in seed germination response to water deficit stress in six baobab (*Adansonia digitata* L.) provenances

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Baobab (*Adansonia digitata* L.) is an important multi-purpose forest tree in sub-Saharan Africa where water deficit stress is the most limiting factor to germination and seedling establishment in natural environments. In the situation of global climate change, droughts are predicted to increase in both frequency and intensity in the Sahel and it is therefore crucial to identify plant genotypes that can germinate and grow under limited soil moisture conditions. Seed germination of six baobab provenances from different agro-climatic zones of Senegal was assessed under controlled water stress conditions using polyethylene glycol (PEG-6000) at the following osmotic potentials: 0, -0.4, -0.8, -1.2 and -1.6 MPa. There were significant germination differences among provenances and across water stress levels. The highest percentage germination (91.23%) was obtained under control conditions and the rate and final seed percentage germination decreased with an increase in osmotic stress. At -0.8 and -1.6 MPa for 10 days, Wélingara and Diana Malary provenances from the humid Sudan zone had the lowest germination rate capacity while provenances from Sahel (Cokki) and Sudano-Sahel (Balla and Gnibi) zones were much less affected. The final germination rate decreased significantly for all six baobab provenances with a decrease in osmotic potential down to -1.6 MPa except for provenances from Gnibi and Balla which showed higher germination rates, Gnibi having the highest values. These latter provenances can be considered as the most drought tolerant ones at the germination stage in the experimental conditions of this study.

Keywords: PEG-6000, drought stress, seed germination, baobab, domestication

Evaluation of 13 Bambara groundnut (*Vigna subterranea* (L.) Verdc.) landraces to drought stress

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Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is an indigenous or traditional African grain legume which is mainly grown as a subsistence crop mostly by women. The crop is mainly intercropped with sorghum and millet and does well in poor and marginal soils. The crop has been described as a drought-tolerant crop and has potential as a food security crop especially in sub-Saharan Africa where crop productivity is greatly affected by drought. Thirteen bambara groundnut landraces were evaluated regarding their response to drought at the Crop Science Department, University of Guelph, Ontario-Canada, in controlled environments. One hundred and fifty six 4-litre pots were filled with sandy loam top soil with a pH of 7.3, organic matter content of 8.4% and total nitrate content of 14.4 mg/kg. N:P:K (20:20:20) was applied at a rate of 4g/pot and watered. Seeds were sown in two walk-in growth chambers with each chamber containing 78 pots. Plants were arranged in a completely randomised design with each landrace replicated in six pots. Growth chamber Photosynthetic Active Radiation was maintained at 230-300 $\mu\text{mol m}^{-2} \text{s}^{-1}$. Growth chamber photoperiod was maintained at 12h:12h, day:dark, temperature of 30°C day and 25°C night and relative humidity of 60%. Plants were irrigated every three days until 30 days after sowing (DAS) when irrigation ceased for the drought treatment until 60 DAS when irrigation resumed. The irrigated treatment was, however, done every three days until the termination of the experiment. Four of the landraces flowered earlier under drought than with irrigated conditions. Stomatal conductance was significantly higher with respect to the irrigation treatment ($P=0.0001$) and landrace ($P=0.02$). Leaf chlorophyll content was significantly higher under irrigated treatment ($P=0.0001$) and landrace ($P=0.0002$). Morphologically, drought stress was observed after 25 days without irrigation. Genotypes responded to drought stress through reduced canopy size, spindle-shaped leaves and vertical orientation of leaflets. 'Tan One' from Tanzania showed the greatest recovery after re-watering 30 days after drought treatment.

Keywords: drought, Bambara groundnut, irrigation, landraces

Production of underutilized crops in climate change scenarios in semi-arid Southern Africa

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As climate change influences crop production, one needs to explore alternative combinations of crops for semi-arid regions of southern Africa. Underutilized crops can be introduced to enhance crop productivity and nutritive value of the smallholders' diets, as well as promoting crop diversification and decreasing water use. This potential can be evaluated using historic and future climate change scenarios by matching them with the underutilized crop characteristics in a crop-climate modelling exercise. Two underutilized crops, both hardy and drought resistant, were tested, namely a cereal, Pearl millet and a legume, Bambara groundnut in a semi-arid region of southern Africa. The FAO-AquaCrop model has been calibrated and evaluated for both Bambara groundnut and Pearl millet (for each of two landraces/varieties), and above-ground biomass production, seed yield and seasonal water use were simulated. The crop yield under baseline climate (1991-2010) was compared to mid-century (2046-2065) using downscaled climate scenarios A2 and B1, from MPI ECHAM 5 and CSIRO mk3.5 climate models for Bloemfontein, South Africa. The higher temperatures predicted under climate change resulted in a shortening of the growth period for pearl millet. The water use efficiency of the pearl millet is higher under the baseline climate conditions than climate change scenarios for both the local and improved varieties. Bambara groundnut landraces that originated from hot and dry climates had lower water use efficiency than those originating from the humid areas, thus influencing adaptability to dry and hot conditions in future climates. The introduction of these or other underutilized crops into existing farming systems will help to diversify the food supply and promote sustainability. These more resilient farming systems will better tolerate the environmental stresses, such as dry spells, drought and high temperatures, expected under future climate scenarios.

Keywords: underutilized crops, climate change, AquaCrop model, Bambara groundnut, pearl millet, water use, yield

Vulnerability and adaptation responses to climate change: the case of smallholder farmers in northern Ghana

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The study assesses the level of vulnerability and adaptation responses of smallholder farmers to climate change and variability in northern Ghana. The livelihood vulnerability index and multinomial logit regression were used to measure the level of vulnerability and to determine the factors that influence the adoption of an adaptation strategy respectively. Smallholder farmers' ranking of adaptation strategies was subjected to the Friedman's test. Primary data were collected through household surveys, community focus group discussions and key informant interviews. Secondary data on rainfall and temperature were also collected. The Upper West Region was found to be the most sensitive region in northern Ghana to climatic impacts. Whereas the Northern Region was found to be the most exposed, the Upper East Region was found to be the most vulnerable in terms of adaptation capacity. Seventeen indigenous climate-related practices and technologies categorized into four indigenous strategies, and sixteen climate-related technologies introduced by research also categorized into four introduced strategies, are identified for use by smallholder farmers in northern Ghana. Timing of the onset of the rainy season which informed planting, and soil and plant health-related strategies were found to be the most important climate-related strategies used by smallholder farmers to adapt to yield risk. Farmer and farm characteristics, institutional setting and environmental characteristics were found to be important in determining the choice of a climate-related strategy. The findings of this study have implications for policy.

Keywords: climate change, vulnerability, multinomial Logit, northern Ghana

Physiological responses of a Bambara groundnut (*Vigna subterranea*) segregating population to mild drought stress

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The effect of mild drought stress on a Bambara groundnut (*Vigna subterranea*) F₅ segregating population derived from the cross between DipC and Tiga Nicuru was evaluated in controlled-environment glasshouses at the FutureCrop Glasshouses, Sutton Bonington Campus in 2012. There were 63 F₅ individual lines and the mild drought stress was imposed from 50 DAS until 92 DAS when a 50% decline in stomatal conductance was observed in the drought plot. Drought stress reduced stomatal conductance significantly with variation observed in the segregating population but not relative water content or carbon (Delta C13) isotope analysis of leaves. Drought stress also did not influence plant growth significantly in terms of estimated days to podding, internode length, peduncle length, pod number per plant, seed number per plant and shoot dry weight. Nevertheless, 100-seed weight and harvest index were significantly reduced by 8% and 15.6% respectively by drought in the segregating population. An increase in stomatal density per leaf area in plants under drought conditions was observed. This showed a negative correlation with 100-seed weight and harvest index ($r=-0.40$; $r=-0.42$) at a significant level of 1%. The response of Bambara groundnut to a short period of water deficit might provide an insight into the instant defence mechanisms of plants against drought when the plants were stressed. The variation observed among the individual lines could also provide candidates that have better tolerance behaviour to drought for future breeding programmes on Bambara groundnut.

Keywords: Bambara groundnut, water stress, stomatal conductance, stomatal density, yield

Influence of climate change on the geographical distribution of neglected and underutilized species (NUS) in Bénin: the case of *Dialium guineense* Willd. (Leguminosae-Caesalpinioideae)

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Climate change is one of the most important threats to plants and animals because of the alterations that it induces in their habitats. This is a challenge since it could impede the domestication and sustainable use of indigenous fruit trees which can contribute to food security in Africa. Our study aimed to identify suitable areas for the propagation of *Dialium guineense* and the potential impact of climate change on the geographic range of this indigenous neglected and underutilized species in sub-Saharan Africa. Climate envelope modelling techniques based on Maximum Entropy (MaxEnt) combined with Geographic Information System (GIS) were used to forecast the current and future suitable habitats for propagation and conservation of the species. Records of the distribution of the species were collected and compared to bioclimatic variables derived from monthly temperature and rainfall data obtained from the Worldclim database. Future predictions were based on two climate models (CCCMA, CSIRO) under the 'A2 scenario of IPCC at 2050'. The results showed that the habitats suitable for the cultivation and conservation of *D. guineense* correspond to Guinean and Sudano-Guinean zones. The CCCMA model predicts that in the event of an increase of temperature associated with rainfall decline, some highly suitable zones will become 'fairly' suitable zones. On the other hand, a decline in temperature associated with an increase in rainfall (CSIRO model) could expand the highly suitable zones of the species by 2050. Bearing these predictions in mind, priority should be given to the domestication of species in the Guinean and southern part of Sudano-Guinean zones which seem to be more suitable for the conservation and cultivation of the species looking towards 2050. However, the northern part of the Sudano-guinean zone may best support ecotypes native to relatively arid zones which could withstand a decline in rainfall.

Keywords: climate change, indigenous fruit trees, domestication, MaxEnt, NUS, Benin.

Genetic diversity of finger millet (*Eleusine coracana*) genotypes under drought stress using RAPD markers

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The present study was undertaken to screen the finger millet genotypes for different responses to drought stress and to assess the genetic diversity among these genotypes with the help of RAPD markers. Initial screening involved growing 27 genotypes under seven different levels of polyethylene glycol (PEG) 6000 (5%, 8%, 14%, 18%, 29% and 25%) in Petri plates in laboratory conditions. No germination was observed at 25% PEG concentration. Different seedling parameters - germination percentage, root length, shoot length, total length, fresh weight, dry weight, tolerance index were analysed for all the genotypes under study. Molecular characterization of these finger millet genotypes was done through 18 RAPD primers. In RAPD analysis the total number of 25 bands was observed among the 27 finger millet genotypes. The number of scorable markers produced per primer ranged from 1 to 4 and size of the products ranged from 250 bp to 1300 bp. The PIC values, a reflection of allele diversity and frequency among the varieties, was highest for 35 ME 10T 23 primer. The PIC value ranged from 0.659 (OPK 11 F) to 0.966 (35 ME 10T 23) with an average of 0.812. The resolving power varies from 0.3704 (35 ME 10T23) to 4.07 (OPJ 13F) with a mean value of 2.89. The genetic similarity coefficient was highest (0.96) for two genotypic pairs PRM 8104 and VL 315 and PRM 8107 and PRM 601. The lowest similarity index (0.28) was recorded for genotype PRM 8109 in pair with five genotypes: PRM 701, PRM 8122, PRM 8104, PRM 6112 and PRM 6122 indicating that they are quite diverse. Cluster analysis by the UPGMA method grouped the 27 finger millet genotypes into two distinct major clusters of 14 genotypes in one cluster and the rest of the genotypes in the other cluster indicating the presence of genetic diversity among the genotypes at the molecular level.

Keywords: drought stress, finger millet, PEG 6000, RAPD marker

Evaluation and identification of suitable finger millet genotypes for higher productivity in combatting climate change

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Finger millet (*Eleusine coracana* L. Gaertn.) is a staple food crop in the majority of drought-prone areas in several East African and South Asian countries. Finger millet is hardy in nature and resilient to adverse climatic factors. The grains are rich in nutrients and the crop yields valuable fodder. An investigation was carried out in the Department of Millets, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore during 2011-2012 to develop high yielding genotypes with best nutritional qualities and high yield potential even under changing climatic conditions using phenotypic selection methods. Initially, 100 finger millet genotypes were evaluated for different productivity and quality traits. Among them, 24 finger millet genotypes were screened based on the yield and nutritional qualities. Selection was based primarily on agronomic traits such as days to maturity, plant height, number of productive tillers per plant, number of fingers per earhead, finger length, 1000 grain weight and grain yield per plant. Grain nutritional quality traits like calcium, iron and zinc content and genetic parameters assessed by the breeders were used as selection tools. The wealth of germplasm accessions with sufficient variability could be exploited properly if suitable selection procedures were followed. Thus breeders can use potential genotypes which have high yields and other desirable traits. It will act as an initiative for utilization of variability and allows the selection of genotypes for different agro-climatic situations. Hence, even under changing climatic and other environmental conditions, direct selection based on yield and yield-contributing traits with high nutrients will help the people affected by malnutrition.

Keywords: finger millet, climate change, nutritional quality, selection and variability

Evaluation of sorghum genotypes to enhance production to cope with climate change in Makueni County, Kenya

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Sorghum is one of the most important cereal crops in the semi-arid tropics. It is a globally cultivated cereal, unique due to its tolerance to drought, water-lodging, saline, alkaline, infertile soil conditions and high temperatures. Sorghum, which originates from Africa, can thrive under conditions and locations where other cereal plants cannot survive due to lack of water, and thus can be used to cope with the effects of climate change which may affect drought-prone areas. However, despite its importance, the potential of sorghum has remained unexploited in Kenya due to low productivity, lack of diversified uses, inadequate product promotion, poor market linkages, an unfavourable policy environment and low adoption of improved varieties. A study was carried out to evaluate fifteen sorghum genotypes (varieties and hybrids) suitable for the Makueni county in Kiboko and Kampi ya mawe locations. Preliminary results showed significant differences ($P \leq 0.01$) in the panicle weight and panicle length of the genotypes. The disease scores were low for both sites, and not statistically significant. The hybrids had higher yields than the varieties. Gadam had the least yield, which correlated to the short panicle lengths. Gadam and one hybrid had a significantly ($P \leq 0.05$) short flowering period. A field day was held for farmers to interact with researchers, extension officers, and sorghum merchants. The farmers reported that their main challenge in sorghum production was the damage from birds, poor yields and poor rainfall. Despite the ready market for the Gadam variety, few farmers were producing it. There is a need for awareness for this market. These results constitute important information in the enhancing of production of sorghum with new varieties and hybrids and marketing.

Keywords: sorghum, varieties, hybrids, production

Methodology mapping for resilient production systems: approaches followed and results from surveys in Bolivia, India, and Nepal

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Agricultural production is dominated by a narrow range of crop species. This fact threatens the resilience and stability of food security in the face of global climate change. Diversification through increased cultivation of neglected and underutilized species (NUS) has the potential to enhance the resilience and adaptability of agricultural systems. NUS are often resistant to marginal and stressful conditions such as drought, cold and water-logging. Despite their great potential, very little is known about how farmers worldwide are using these species to cope with climate change. This study sought to shed light on this issue. Two thousand three hundred and fifty three farmers were interviewed in three countries (India, Nepal, Bolivia) to assess their perceptions of climate change, which crops are more susceptible and resistant to the changes, and what actions they have taken to cope. Almost all farmers interviewed in the three countries (86% to 99%) noticed a change in the weather over the last 20 years. A common action to deal with climate change was to plant new crops or varieties. Preliminary analysis indicated that local crops are often perceived to be resistant to climate change. In Nainital, India the crop listed by the most farmers as resistant to climate change (74%) was finger millet, which was recognised by about double the amount of farmers as resistant to climate change compared to corn and barley. In La Paz, Bolivia, 34% of farmers perceived quinoa as being most resistant. In Begnas, Nepal the top five-mentioned resistant crops were also NUS, i.e. taro, ginger, finger millet, yam and turmeric. Lack of information on climate change was identified as a major challenge in coping strategies. Overall, results indicate that NUS have great potential to help adapt food production systems to climate change and that farmers are already exploring such a potential in their coping strategies.

Keywords: climate change, resilience, diversification, Neglected and Underutilized Species (NUS), farmer survey

***In-vitro* screening of swamp taro (*Cyrtosperma merkusii*) cultivars for tolerance to salinity**

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Swamp taro (*Cyrtosperma merkusii*), is not only a culturally important crop but also a staple food source for atoll countries and communities in the Pacific region. It is globally considered as a neglected and underutilized species, but still well utilized by Pacific countries for food and nutritional security. Salt intrusion and rising sea level are major problems affecting food security of these atoll countries, and finding resistant cultivars to salt intrusion is a big challenge. The study investigated two methods for establishing salinity tolerance of seven swamp taro cultivars. All seven cultivars were exposed to varied salt (sodium chloride) concentrations for four weeks ranging from 0% to 4% using two *in-vitro* screening methods. The salinity concentrations determined for the research were based on the Suva coastal seawater salinity level and averaged 3.2% (measured using a refractometer). The first method involved the supplementation of different treatments containing basal Murashige and Skoog medium with varied salt solutions: 0% (control), 0.8% (0.8g/L), 1.6% (1.6g/L), 2.4% (2.4g/L), 3.2% (3.2g/L) and 4% (4.0g/L) at the initial stage of the research prior to planting of fully grown plantlets. The second method involved the incremental addition of 1% salt concentration weekly to different treatments containing basal MS medium already planted with fully grown plantlets until the desired individual salt concentrations of 1%, 2%, 3% and 4% respectively were reached. Weekly measurements were taken based on six morphological parameters. Assessment of salt tolerance of cultivars was based on averages of swamp taro responses to different salt concentrations using two methods. Four cultivars, Natutebubua (KB05), Teimanra (KB06), Kaiura (KB09) and Via Dina (FJ02), were identified as tolerant varieties to 1%, 2%, 3% and 4% based on their responses to two methods. The incremental addition of salt method was optimal for screening salt tolerance in swamp taro cultivars. The four tolerant cultivars identified have exhibited higher mean values of tolerance according to the five morphological parameters. Lower mean values with plant susceptibility showed highest susceptibility to 4.0% salt. All seven varieties screened using the supplementation method tolerated 0.8% salinity level.

Keywords: swamp taro, *Cyrtosperma merkusii*, *in vitro* screening, salt tolerant varieties, Pacific crops and trees

Neglected and underutilized crops for food and income security in marginal environments

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Neglected and underutilized crops (NUS) are known to be more resilient and better adapted than staple crops to grow in marginal environments constrained by water scarcity, poor soils and other such yield-limiting factors. Studies conducted in the United Arab Emirates (UAE) showed that underutilized crops such as quinoa, cluster bean, safflower, salicornia and leaf mustard are of value in providing cost-effective and long-term solutions to sustain agricultural production in areas stressed with diminishing quality and quantity of irrigation water, nutrient-poor soils and high temperatures. Among the crops studied, while quinoa and mustard are also nutritionally rich and can thus play a crucial role in combating vitamin and micronutrient deficiencies frequently experienced by inhabitants of marginal environments, safflower, cluster bean and *Salicornia* are multi-purpose crops that could increase farm income through diversifying products and creating new agro-industries. Research to improve the productivity and value of these crops, and to encourage them to be more widely cultivated, would effectively contribute to food, nutritional and income security of the smallholders living in marginal environments.

1.4 Utilization, processing and post-harvest

Collective action in managing a *Ricinodendron heudelotii* (Baill. Pierre ex Pax) kernel extraction machine: adoption drivers and constraints in Southern Cameroon

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Farmers' organizations play an important role in technology development and adoption. A challenge, however, remains to make farmers organizations benefit all members through its activities. Previous studies explored new post-harvest techniques for kernels of *Ricinodendron heudelotii* (njansang), an important source of rural income in southern Cameroon, in terms of technical performance, profitability and livelihood improvement. In this paper we (i) characterize njansang producers' groups in southern Cameroon from the point of view of their functioning, structural, and socio-economic characteristics, (ii) analyse the level of collective activities of njansang and also the level of utilization of extraction machines and (iii) identify factors associated with the adoption of njansang extraction machines. We compared situations with (a) presence of the machine + active development support, (b) presence of the machine as such, and (c) absence of either. A survey was carried out and a random sample of 120 njansang producers, stratified by village, was used in the study. A high proportion of collected data was qualitative. Therefore, we used multiple correspondence analysis for data analysis. Results showed that the adoption of njansang extraction machines was mostly related to distance of the machine to the nearest group members. Similarly, investments in collective njansang extraction would improve management capacity and utilization of the machines.

Keywords: agricultural innovation, agroforestry, tree products, farmers' organizations, post-harvest, smallholder producers.

Progress in agronomic, nutritional and engineering development research on the tree crop *Treculia africana*

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African breadfruit (*Treculia africana* var. *africana* Decne) is an underutilized tree crop in the family Moraceae. An evergreen forest fruit tree in tropical Africa, it produces large round compound fruit which is covered with rough pointed outgrowths. The seeds are buried in spongy pulp of the fruits. It is an important food item in parts of tropical West Africa, and is variously cooked as pottage, or roasted and sold with palm kernel (*Elaeis guineensis* Jacq) as a roadside snack. The flour has high potential usage for production of pastries. The seeds are very nutritious and constitute a vital source of vitamins, minerals, proteins, carbohydrates and fats. This paper reports recent efforts to upgrade the value chains of some varieties of *Treculia africana* found in parts of Ghana and Nigeria. Particular attention is paid to progress in agronomic, nutritional and engineering development research, as well as consumer preferences after alternative processing operations. The agronomic studies showed that seed sterilization resulted in a lower proportion of deformed seedlings. About 63% of seedlings arising from seeds previously treated with 10% dilution of NaOCl had true leaves and each seedling thereof had more leaves. The nutritional studies determined the best methods of seed extraction and de-mucilagination for use in high-quality flour production. The production of pasta, breakfast meal and good-quality oil are also demonstrated. Design, construction and testing of a continuous flow machine for de-pulping the partially fermented fruits resulted in a potentially significant reduction in the drudgery associated with manual processing. The best conditions for de-hulling the seeds after parboiling were determined. Consumer preferences for several derived products were very high.

Management strategies of perceived risks associated with *Moringa* products by consumers in Ilorin Metropolis, Kwara State, Nigeria

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This study focused on examining the management strategies of perceived risks associated with *Moringa* products by consumers in the Ilorin metropolis with a view to highlight the perceived risks associated with its consumption, assess the different strategies employed by consumers to manage or cope with the perceived associated risks and to examine socio-economic determinants of consumers' consumption behaviour in relation to the perceived risks. Primary data employed in the study were collected with the aid of a well structured questionnaire; 116 respondents were randomly selected. The data were analysed using descriptive statistics and the Tobit regression model. The result shows that the major risks associated with *Moringa* consumption in the study area were nutritional loss through processing (30.9%), contamination during processing (25.8%) dryness of the mouth (16.3%), stomach ache (12.8%) and constipation (10.2%). It was also found that most of the respondents did nothing about the risk associated with *Moringa* consumption, while some of them reduced the quantity consumed per dose or frequency of consumption. Awareness of risk and consumption of *Moringa* powder were found to have a significant effect on consumers' attitude towards the perceived risk ($P=0.1$). It is therefore recommended that awareness of *Moringa* for food security and good health should be enhanced. The study also recommends the need to educate processors and consumers on safe and appropriate post-harvest handling procedures.

Keywords: management strategies, perceived risk, *Moringa* consumption, Ilorin Metropolis, Kwara State, Nigeria

Effect of post-harvest losses of traditional vegetables on market participation by smallholders in Tanzania

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Smallholder production of traditional leafy vegetables is an important activity even though these crops are perishable and prone to high post-harvest losses. We examined post-harvest losses in traditional leafy vegetables compared with cash crops to estimate the impact of post-harvest losses on market participation and marketed surplus. The study analyzed 240 farm households from the Arusha, Tanga and Morogoro regions in Tanzania that cultivate amaranth (*Amaranthus* spp.) and/or produce tomato as a cash crop. Systematic random sampling was used to draw samples for the survey and an econometric analysis was conducted. More than 81% of respondents who grew tomato reported spoilage between harvesting and selling, whereas only 39% of amaranth growers experienced spoilage in their crops. Loss due to mechanical damage was 2.35% for amaranth and 17.05% for tomato. Economic losses were reported to be 131 TSh for amaranth and 2057 TSh for tomatoes per transaction. Although post-harvest losses were higher for tomato, field observations showed that market participation in terms of the number of tomato producers was high compared with amaranth growers. Tomato cultivation is considered to be capital-intensive compared to production of traditional leafy vegetables. To improve the livelihoods of smallholders, it is important to increase their access to better technologies and infrastructure for amaranth production and value addition, which may result in lower post-harvest losses and increased market participation.

Keywords: post-harvest losses, traditional African leafy vegetables, market participation

1.5 NUS for nutrition and health

Anthelmintic effects of a diet containing a traditional plant *Viscum verrucosum* on faecal egg count and eosinophils of naturally infected Tswana goats

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Twenty (1-year old) female goats, naturally infected by internal parasites, were acclimatised to individual pens and fed for three weeks and then blocked for live weight (LW) and faecal egg count (FEC) and randomly allocated to four treatments; a standard diet (SD; CP = 12%; n = 5; LW = 24.1kg; FEC = 2640 eggs per gram - epg), a high protein diet (HP; CP = 16%; n = 5; LW = 25.7kg; FEC = 2630 epg), a *Viscum verrucosum* diet (VV; CP = 12%; n = 5; LW = 26kg; FEC = 2720 epg) and a standard diet dosed with a commercial drug (valbazene) (SDD; CP = 12%; n = 5; LW = 25kg; FEC = 2800 epg). Faecal samples were collected weekly while blood samples were collected from the jugular vein, at the beginning of the experiment and at 21, 35 and 49 days. Live weight was measured at the beginning and end of the study. There was a highly significant ($P < 0.001$) treatment and treatment \times time interaction on FEC whereby VV and SDD animals excreted fewer eggs on day 28, 35, 42, 49 and 56. Eosinophil counts were significantly lower ($P < 0.001$) on day 35 and 49 in goats fed VV and in those dosed with valbazene. There was no significant difference in LW daily gain between the treatments (HP; 21.4, SD; 44.6, SDD; 39.2 and VV; 53.6g/d; $P > 0.05$) indicating that protein supply had not been improved. It however, also shows that at the inclusion rate used in the current study, *V. verrucosum* was not detrimental to growth. A *V. verrucosum*-based diet was as effective as the chemical, valbazene, in reducing FEC, indicating that the use of natural flora may be a beneficial option for low-resource farmers who cannot afford to purchase drugs to control internal parasites. Eosinophils were reduced in VV and SDD goats, suggesting that the lack of eosinophils is associated with reduced FEC or worm burden. In contrast, the high eosinophil counts found in the HP and SD goats may point to the preservation of parasites as a mechanism to facilitate a future response to re-infection.

Keywords: eosinophil, faecal egg count, internal parasites, Valbazene, *Viscum verrucosum*

Simple sequence repeat (SSR) polymorphisms and the relationship with phytochemical composition in Nigerian sesame (*Sesamum indicum* L) cultivars

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Genetic characterization of Nigerian sesame accessions (*Sesamum indicum* L.) and its association with composition of phytochemicals with a nutritional and health value was investigated using simple sequence repeats (SSRs). High genetic variability was found among Nigerian sesame genotypes with the repeat motifs (TC₁₂-TC₂₅) generated from two highly informative primer pairs. Based on the length of repeats, thirty accessions were divided into six main groups. Two cultivars did not belong to any group when an unweighted pair-group method with arithmetic average cluster analysis was applied. The average allele per SSR locus was 4.0 and the genetic distances among the accessions ranged from 0 to 0.20. Phytochemical amounts including tannins, flavonoids, saponins glycosides and alkaloids varied in different accessions with no clear association to SSR length except for one SSR (TC₁₂) in accession Ciano 27, which had a possible association with a low flavonoid concentration.

Keywords: sesame, genetic characterization, SSR-markers, phytochemicals.

Lesser known underutilized seed oils: potential source of food for the African community

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Access to adequate and nutritious foods is sometimes expensive as a result of industrial demand for food as feed stock for the agro-allied industries and as a potent source of the much-needed foreign exchange. To deal with these serious problems of food insecurity, five lesser-known underutilized seed oils from Nigeria belonging to the leguminaceae families were investigated for their properties, composition and edibility. Oil was extracted from the seeds using a soxhlet extractor. The oils and seeds were characterized using a standard method of analysis while mineral composition was analysed using atomic absorption spectroscopy. Lipid classes and triglycerides of these oils were isolated by column chromatography and were further identified and quantified using HPLC. Fatty acid composition of the oils was determined using GC while unsaponifiable components were identified by GC-MS. Oils were subjected to toxicity/edibility tests by feeding them to two week-old albino rats at 5% feed composition for 90 days and later screened for histopathology, hematology and biochemical analysis. The oil content of the seeds varied. The percentages of carbohydrate and protein of the seeds ranged from 9.3 to 62.7 and 14.0 to 47.4, respectively. The most abundant mineral in the seeds as well as the oils was potassium. Palmitic, stearic, oleic, linoleic, and linolenic acids were found in the oils. Neutral lipids and molecular species with equivalent carbon chain number C₃₆ to C₅₀ were prominent in the oils. Phosphatidylethanolamine was the major phospholipid while digalactosyldiacylglycerol was the dominant glycolipid found in these oils. The unsaponifiable matter included: hydrocarbons, sterols, vitamins and phytol. Some of the oils appeared to be slightly cardiotoxic with moderate myofibre hemorrhage and congestion of the spleen of rats fed with the oils. Our findings have proven that these oils have potential food value after slight refining.

Keywords: fatty acid, food, leguminaceae, lipids, toxicity

Analysis of anti-infective compounds produced by marine endophytic fungi found in Ghana

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Based on the fact that a great variety of these fungi are readily found in Ghana, a pilot project of screening marine endophytic (ME) fungi found in Ghana for the presence of bioactive new chemical entities (NCEs) against clinically relevant microbial pathogens has been ongoing for the past two years. In the initial phase, 29 ME fungi were isolated, cultured and ethyl acetate extracts of the cultures were tested for biological activity. Using the disc diffusion method, the extracts were tested against *Staphylococcus aureus*, *Escherichia coli*, *Candida albicans* and *Mycobacterium smegmatis*. This resulted in the identification of many extracts with potent activities. Overall, 28 out of 29 of all the extracts tested showed activity against the four organisms tested. We recorded 22/29 with activity against methicillin-resistant *S. aureus* (MRSA), 6/29 for *Escherichia coli* and *Candida albicans* four of which was by the same set of ME-fungi against each organism. The highest frequency of activity detected was anti-mycobacterial activities, scoring 27 out of the 29 extracts tested constituting a positive hit rate of 93%. When a higher cut-off point of 14mm for the zones of inhibition is considered, the positive hit rate declines to 65.5 % of all the 29 fungal extracts tested. These results provide the proof of concept that ME-fungi found in Ghana are a potential source of novel anti-mycobacterial agents, anti-MRSA compounds and anti-microbials in general. The anti-mycobacterial activities shown so far were determined on the basis of growth inhibition using the disc diffusion assay. While it is important to isolate compounds that are active against replicating cells, persistence of non-replicating *Mycobacterium tuberculosis* cells in the presence of powerful antibiotics constitutes the Achilles' heel of tuberculosis chemotherapy. We are therefore incorporating a screening strategy that uses dormant non-replicating mycobacteria cells to test our library of ME-fungal extracts to identify compounds of this class of compounds.

Characterization of the ripe edible shea nut (*Vitellaria paradoxa* C.F. Gaertn.) fruit pulp for dietary minerals and metabolites in Ghana

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The Shea nut (*Vitellaria paradoxa* C.F. Gaertn.) tree is most known for its value as an oil plant. However, the ripe Shea nut fruit is edible, and considered a major source of food. The fruit-picking season of Shea nuts starts between May and June each year, and ends in September depending on rainfall. The Shea nut season thus coincides with the period when there is food shortage and hunger in the Guinea and Sudano savanna regions of West Africa. As a result, the ripe Shea nut fruits are eaten in abundance during this period, and thus serve as a source of food security. So far, however, no information exists on the dietary value of the edible flesh of Shea nut fruits. This study assessed the nutritional composition of ripe Shea nut fruits collected from four villages in the Upper West Region of Ghana, using ICP-MS and HPLC techniques. The data revealed high concentrations of essential dietary minerals in the pulp. For example, nutrient concentrations ranged from 600 to 820 mg/kg for P, 1348 to 1458 mg/kg for K, 5000 to 6120 mg/kg for Na, 880 to 1040 mg/kg for Mg, and 440 to 500 mg/kg for S. The trace elements similarly showed high concentrations in ripe Shea nut fruits, with Fe being the most abundant in edible flesh of Shea nut fruits. Micronutrient concentrations in edible Shea nut fruits ranged from 223 to 672 mg/kg for Fe, 7 to 19 mg/kg for Mn, 7 to 10 mg/kg for Zn, 8 to 10 mg/kg for B and 1.3 to 1.6 mg/kg for Cu. HPLC analysis of ripe Shea nut fruits also revealed high concentrations of sugars such as fructose, glucose, sucrose and mannitol in the edible flesh, with fructose generally occurring at greater levels irrespective of fruit collection site. Although amino acids such as Glu, Gln, GABA, Cys, Met, and Lys were generally absent in fruit pulp of Shea nuts, Pro occurred in very high concentrations independent of collection site. The results are discussed in relation to human nutrition/health, and the potential for making Shea nut fruit jam, thus increasing the value chain of the Shea nut industry.

Keywords: nutrient elements, sugars, amino acids, Shea jam

Assessment of fonio as a dietary intervention in Northern Ghana

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One of the world's greatest challenges is to secure an adequate food supply that is healthy, safe and of high quality for all in an environmentally sustainable manner. With the growing demands of an ever-increasing human population, it remains unclear how our current global food system will sustain itself. Compounded with climate change, ecosystems and biodiversity under stress, population growth and urbanization, social conflict and extreme poverty, there has never been a more urgent time for collective action to address food and nutrition security globally. It is in this quest that research has identified varieties of indigenous crops of outstanding quality of which fonio stands out in terms of nutritional composition. Fonio, a neglected and underutilized species is one of the candidate native crops within the West African sub-region for curbing growing malnutrition on the continent through the value chain approach. The value chain approach for nutritional goals is a set of strategies through which value is added to products for improvement of nutrition among vulnerable groups, while creating benefits for stakeholders. Strategies in a value chain approach comprise agricultural strategies, processing, and consumer-oriented actions to enhance acceptability. To achieve these objectives, specific research questions were investigated through baseline assessment of (i) nutrition (iron) status, iron intake and adequacy to define the nutritional context for operating the value chain approach; (ii) assessment of socio-cultural acceptability of fonio as a strategic entry point for consumer-oriented activities; (iii) investigating processing (de-phytinization and fortification) as a strategy for adding nutritional value to fonio. Fonio so far has received but a fraction of the attention accorded to well-known cereals such as sorghum, pearl millet, and maize, and a mere trifle considering its importance in the rural economy and its potential for increasing the food supply as well as alleviating nutritional challenges in rural areas. Considering the advantages of this underutilized crop, as one of the fastest growing cereals, considerable ecological adaptability, high amino acid content, suitable for people with gluten intolerance and suitable for making many value added products, fonio is undoubtedly a grain of life for the alleviation of malnutrition, extreme poverty and insecurity among vulnerable groups especially children in the rural areas of Africa.

Keywords: fonio, value-added products, malnutrition, infants, underutilized

Evaluation of the nutrient and health potentials of wild and domesticated trifoliate yam (*Dioscorea dumetorum*) in Nigeria

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The bitterness, toxicity and long cooking time associated with wild *D. dumetorum* have led to its neglect and near extinction. Another cultivar which cooks faster and with little or no toxicity was developed and domesticated. The objective of this work was to assess the nutrient, anti-nutrient and phytochemical components of the wild and domesticated *D. dumetorum*. Proximate composition was conducted using the Standard methods of Association for Official and Analytical Chemists. Gas chromatography/mass spectrophotometry was used to identify the phytochemical components. The results illustrated that there were differences in the nutrient and phytochemical composition of the cultivars investigated. The wild *D. dumetorum* had higher crude protein (11.41%), ash (3.41%), saponin (3.76%) and alkaloid (3.23%) contents than the domesticated cultivar. Thirteen compounds were identified in wild *D. dumetorum* while eleven were identified in the domesticated cultivar. Fatty acids such as cis-oleic acid, lauric acid, myristic acid and palmitic acid were identified in the two *D. dumetorum* cultivars. Phenolic compounds such as 3,5-di-*t*-butylphenol and 3-decanone-5-hydroxy-1-(4-hydroxy-3-methoxy phenyl) which have been reported to have potential antioxidant activity were identified in the wild cultivar. A compound, decahydro{1,7}naphthyridine was identified for the first time in wild *D. dumetorum*. This work established the nutritional and phytochemical contents of these underutilized cultivars of yam and recommended the increased utilization of wild *D. dumetorum* as a means of ensuring food security.

Keywords: trifoliate yam, phytochemical composition, wild, domesticated.

Nutrient concentration of anchote (*Coccinia abyssinica*) plant parts at different harvesting dates and *in situ* storage

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Anchote is an indigenous root crop widely grown in the southwestern and southern parts of Ethiopia. Traditionally, farmers use *in situ* stored Anchote tuberous roots with the belief that nutrient concentration increases over time. Thus, the study tested this farmers' hypothesis, by investigating the nutrient contents of anchote as a function of harvesting dates (4, 7, 10, 13 and 16 months after planting) and *in situ* storage. The fresh and dry tuberous root yields varied significantly ($P < 0.0001$) according to the harvesting dates and *in situ* storage. Extending the harvesting dates from the 4th to the 7th month increased fresh and dry tuberous root yield by 450% and 449%, respectively. Afterwards yield appears to decline. Strikingly, anchote leaf and tuber tissues exhibited higher crude protein and nutrient concentrations than anticipated values for most root and tuber crops. The nutrient concentrations in anchote tuber are by far higher than that found in equivalent weights of potato (*Solanum tuberosum*), yam (*Dioscorea abyssinica*) and cassava (*Manihot esculenta*) tubers. Nutrient analysis revealed that Anchote tubers contain 19g N, 122.6g K, 7.4g P, 5.1g Ca and 316 mg Fe kg⁻¹ of dry weight. This shows that anchote can contribute more nutrients than equal amounts of potato tuber and yam roots, which contain (15g N, 20g K, 2.4g P, 0.78g Ca and 75.2mg Fe) and (13g K, 0.45g Ca and 0.15g Fe) kg⁻¹ dry weight, respectively. Anchote tuber Ca, K, and Fe nutrient contents are also much higher than that of the indigenous root crop, *Dioscorea abyssinica*, which contains 0.9g Ca, 3.9g K and 0.18g Fe kg⁻¹ dry weight. Likewise, anchote leaf contains comparable amounts of nutrients and ash to those of cucumber and swiss chard leaf. Overall, the results indicated that the underutilized indigenous root crop, anchote could be a healthy food crop with potentially equal or even higher mineral elements compared to other exotic root and tuber crops.

Keywords: anchote, harvesting date, leaf, nutrient, tuber,

Wild and semi-wild edible plants: diversity, use in household food sovereignty in remote parts of southern Ethiopia and nutritional benefits

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Food sovereignty and malnutrition remain central concerns in Ethiopia. Promotion of dietary diversity and nutrient-dense traditional foods comprise vital strategies to tackle these challenges. The objective of this investigation was to record and analyse indigenous knowledge and practices of Konso and Hamar communities (south Ethiopia) regarding the use of wild and semi-wild edible plant species (WEPS) and evaluate their nutritional quality and anti-nutritional factors. It also aimed to study the effect of processing on anti-nutritional factors, carotenoids and antioxidant activity of vegetables. Ethnobotanical data on WEPS were collected using qualitative and quantitative tools. Community-based surveys involving 670 households were also conducted to investigate attitude and practice on consumption and related issues on WEPS. Nutritional and other factors were determined using standard methods.

The study revealed 240 edible parts from 206 WEPS, most of which were part of the diet in Hamar and/or Konso but with different intensity of use at household and temporal scales. The extent of use was mainly dependent on the level of food stock at the household level and accessibility of WEPS. Some of the WEPS are threatened by destructive harvesting for different purposes. The study further indicated that green leafy vegetables (13) are rich in minerals (12.5-25.6%) and protein (20-36%, dry basis). Carotenoid profiles were affected by drying but not blanching for a short duration. Drying and blanching reduced the level of most anti-nutritional factors (phenolics, tannins and oxalates but not phytic acid) and antioxidant activities of the vegetables. The study helped to understand the diversity of WEPS in Hamar and Konso, the level of use and nutritional benefit. Drying (mainly under direct sun) vegetables should be avoided to ensure retention of constituents of nutritional and biomedical importance. The findings are important for the conservation and sustainable use of the edible parts, the promotion and development of selected WEPS.

Velvet bean (*Mucuna pruriens*) in monogastric animal nutrition: effect of some local processing methods

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Velvet bean (*Mucuna pruriens*) plants are widely used as a cover crop in many tropical countries. Despite it yielding heavily in seeds, the crop is little-used for human or animal nutrition. Available data on its nutritional value indicate that the seed is high in protein but contains toxic substances which limit its use in monogastric animal feeds. We examined the effect of some local processing methods (cooking, toasting, soaking in water or calcium hydroxide solution prior to cooking and, cracking the seeds prior to soaking and cooking in water or maize-cob-ash solution) of velvet bean on the performance of broilers, laying hens and pigs in different experiments. The proximate compositions of velvet bean subjected to the various processes varied considerably depending on the type of process. Whole velvet bean cooked for 1hr in water allowed for 10% inclusion in broiler diets while velvet bean soaked for 48 hr in water or calcium hydroxide solution before cooking for 1 hr allowed for 20% inclusion. Cracked velvet bean soaked in water before cooking in water improved the performance of broilers or laying hens at 20% inclusion and pigs at 40% while cooking in maize cob ash solution improved broiler performance at a 30% inclusion level. This paper discusses various methods by which the nutritive value of VB can be improved for monogastric animals and calls for its development as an economic crop in order to alleviate the current pressure on soybean and groundnut meals.

Keywords: velvet bean, processing methods, proximate composition, monogastric, performance

***In vitro* calcium bioaccessibility in *Moringa oleifera* vegetable leaves: a potential plant food to increase dietary calcium intake in developing countries**

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Low calcium intake, poor calcium absorption, excessive calcium losses, or some combinations of these factors contribute to calcium deficiency diseases. Calcium deficiency can lead to osteoporosis, reduced bone mass, hypertension and colon cancer amongst other diseases. Studies have reported that *Moringa oleifera* is a better source of vitamins and minerals than most vegetable plants. A study was conducted to assess the availability, digestibility and bioaccessibility of calcium in *M. oleifera* leaves grown in Malawi and India. *Moringa oleifera* leaf samples were collected from the low-lying hot areas of Lilongwe and Karonga in Malawi and another sample originating from India was obtained for the study. Sweet potato and spinach leaves were obtained from produce markets in Cary, USA and were used as a control for the study. Calcium content was analysed in *M. oleifera* leaf powder, sweet potato and spinach leaves using an atomic absorption spectrophotometer. This was followed by an *in vitro* digestion and absorption process to determine calcium digestibility and bioaccessibility. Data were analysed using the SAS software programme. The results indicated that *M. oleifera* had significantly higher calcium content, higher calcium digestibility and higher calcium bio-accessibility than sweet potato leaves and spinach leaves ($P < 0.05$). The results also showed that there was a statistically significant difference in percentage calcium content between the *M. oleifera* samples from India and the two samples from Malawi. The digested calcium levels in the two *M. oleifera* samples from Malawi were similar. Results showed that *M. oleifera* leaves are rich sources of calcium and the calcium in *M. oleifera* can easily be absorbed into our bodies in comparison to sweet potato and spinach leaves. Therefore, including *M. oleifera* leaves into low-calcium diets can reduce calcium deficiency diseases in developing countries like Malawi where milk, the main calcium food source, is relatively little consumed.

Keywords: calcium bioaccessibility, *Moringa oleifera*, Malawi, developing countries

Ethnobotanical investigation of three leafy vegetables [*Alternanthera sessilis* (L.) DC., *Bidens pilosa* L., *Launaea taraxacifolia* Willd.] widely consumed in southern and central Benin

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To document indigenous knowledge and farmers know-how related to the leafy vegetables, *Launaea taraxacifolia*, *Bidens pilosa* and *Alternanthera sessilis*, an ethnobotanical investigation, using participatory approach research methods and tools, was conducted in 19 villages randomly selected across ethnic and agro-morphological zones of southern and central Benin. The geographical distribution of the three species was established and the southern area appeared suitable for an *in situ* conservation programme of genetic diversity of the three species. Respectively 11.11 %, 55.56 % and 90 % of the respondents reported that *Launaea taraxacifolia*, *Bidens pilosa* and *Alternanthera sessilis* are still harvested from the wild (level 0 of domestication) while 22.22% and 16.67% of respondents reported that *L. taraxacifolia* and *B. pilosa* are being cultivated (level 4 of domestication). Of the respondents, mostly women were involved in harvesting and the most common harvest method was uprooting the plant and cutting plant stems. The study revealed the existence of morphotypes resulting in the identification of different varieties of *L. taraxacifolia* (three varieties), *B. pilosa* (two) and *A. sessilis* (two). The frequency of consumption of each of the leafy vegetables and its consumption method varied according to the ethnic group. Regarding methods of preparation, sauce made from fresh leaves was reported only for *L. taraxacifolia* while pre-cooked leaves were otherwise used. The respondents also reported that these leafy vegetables possessed in addition to their culinary value several medicinal virtues; *L. taraxacifolia* was the most valued medicinally, and is used for the prevention or healing of 21 diseases with 16 possible pharmacological functions. Further research is required on the biochemical and phytochemical characterization of the genetic diversity of these species as well as the effects of processing methods on their nutritional value.

Keywords: Benin, cultural practices, domestication, leafy vegetable, morphological diversity.

The use of artisanal popping machines in Andean countries causes lead contamination of expanded grain products

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Popped Andean grains that are informally produced and traded are very popular in the Andean countries and particularly appeal to infants and children because of the pleasant texture and added flavourings. Anecdotal evidence for lead contamination of these products prompted the present study. The content of lead was determined by atomic absorption spectrophotometry in samples from three different sources: i) unprocessed grains of quinoa (*Chenopodium quinoa*) and cereal grains obtained from commercial sources, ii) popped grains from the aforementioned species obtained from rural and urban markets in Peru and from small-scale processors using traditional batch processors, iii) popped grains obtained from batch processors that are essentially the same as the traditional ones but are built of stainless steel and avoid the use of lead. Detected levels of lead were, in general, below detection limits in both unprocessed grains and popped grains from the improved design machine, while popped grains from the traditional machine exceeded allowed permissible levels of lead. These data and circumstantial evidence pointed to the identification of leaden lids in the traditional machine as the cause for lead contamination. A monthly consumption of one kilogram of popped grains, which is plausible and may actually be far exceeded, translates into an average weekly lead intake for children, which is many times the level allowed under FAO/WHO guidelines. Interviews conducted with producers of popped grains that use the artisanal popping machine have shown rampant unawareness of the problem and continued use of lead in popping machines. Worryingly, similar machines have also appeared in sub-Saharan Africa. The results are discussed in relation to the common development narrative that presents small-scale processing as a perspective for value addition and “empowerment” of the poor but typically is oblivious to the lack of food safety in cottage industries.

Keywords: Andean grains, *Chenopodium quinoa*, small-scale processing, lead contamination

Effect of malting periods on the chemical and anti-nutrient composition of mung bean malt

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The objective of the study was to evaluate the nutrient content of mung bean malt to be used in complementary food formulations. The study is part of the effort to provide home-based complementary foods that can be cost-effective for low-income rural and urban poor in developing countries and to diversify the use of mung bean seeds. Mung beans (*Vigna radiata*) seeds were sorted, steeped in water, drained and malted for 24, 48, 72 and 96 hours. Mung bean malt was dried, dehulled, milled and sieved with a sieve of mesh size 200µm to obtain fine flour. The flour samples were analysed for pH, titratable acidity, proximate, minerals and anti-nutrient composition using standard methods. The results revealed a gradual decrease in pH from 6.8 in unmalted mung bean flour to 5.1 in mung bean malted for 96 hours. The total titratable acidity for unmalted mung bean flour was 0.057% which gradually increased to 0.143% for mung bean malted for 96 hours. The values for protein, ash and crude fibre contents increased, as malting periods increased, from 30.77% ,1.95%, 3.11% (0hr) respectively to 31.47%, 4.14% and 3.49% respectively at (96hrs). The length of malting caused a decrease in carbohydrate and fat content of mung bean malt from 52.94% to 33.63% and 4.61% to 0.52% respectively. There was a significant increase in all the minerals analysed except for zinc content which significantly decreased as malting period was increased. There was a decrease in the anti-nutrient contents (phytate, tannin and oxalate) of mung bean flour with an increase in malting period with the lowest values obtained in the 96 hour-malted sample.

Keywords: malting periods, complementary foods, mung bean, nutrient composition

Nutritional security and economic prosperity through underutilized vegetables in the North-eastern Hill Region of India

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Underutilized vegetables are becoming more widely and effectively deployed to address malnutrition, poverty and economic prosperity. They constitute essential biological assets of the rural poor and can contribute to improving the wellbeing of millions of tribal populations. Underutilized vegetables are rich in vitamins, minerals and other health promoting factors including high antioxidant activity. They play a major role in the diversification of diet leading to a more balanced source of micronutrients. Furthermore, underutilized vegetables possess resistance to several biotic and abiotic stresses. The North-eastern Hill region of the India is endowed with enormous genetic diversity of underutilized vegetable crops. There are several minor/underutilized cucurbitaceous vegetables which are grown and consumed by tribals of the region. These are mainly *Cucumis hystrix*, *C. trigonus*, *Luffa graveolens*, *Momordica macrophylla*, *M. subangulata*, *Trichosanthes cucumerina*, *T. khasiana*, *T. ovata* and *T. truncata*. Nutritious pods of *Parkia roxburghii* are consumed as staple legume vegetables in Manipur and Mizoram. Similarly, *Mucuna pruriens* is considered one of the most preferred legume vegetables in the tribal people of Nagaland. A vast reservoir of leafy vegetables falls under underutilized vegetables, which are a rich source of vitamins, minerals and fibres. Furthermore, they have been a traditional part of cropping systems, especially in home gardens. A number of underutilized vegetables possess several desired medicinal properties. *Ipomoea aquatica* an underutilized aquatic vegetable which is plentiful during the rainy season in most parts of West Bengal and Orissa is orally administered to alleviate disorders like jaundice and nervous debilities. Despite the immense potentials of underutilized crops, they are not attracting proper attention owing to a lack of seeds, inadequate information on their use and importance, lack of information about their performance and input requirements, and insufficient information on how underutilized vegetables can fit into production systems. In this paper various researchable and developmental issues related to underutilized vegetable crops have been discussed.

Keywords: underutilized vegetables, lesser known vegetables, North-eastern Hill (NEH) region, genetic diversity

Theme 2: Upgrading value chains of neglected and underutilized species

Successful income generation from NUS relies on effective value addition strategies that take a systems perspective and involve multiple stakeholders. Abstracts within this theme present experience and lessons learned related to production, processing and marketing of NUS and how these efforts have benefited, or can benefit smallholder farmers in particular. Aspects covered include seed systems, storage, value addition and marketing, as well as the role of value chain actors – operators, service providers, and regulating and policy institutions – in upgrading value chains.

Effect of drying method and variety on functional properties of trifoliolate yam (*Dioscorea dumetorum*) flour

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The effect of drying method and variety on the functional properties of trifoliolate yam (*Dioscorea dumetorum*) flour were investigated in this study. Flour was produced from yellow and white varieties of trifoliolate yam using sun drying, solar, oven (40°C), and cabinet (40°C) dryers, respectively. Some functional properties of the flour were determined using standard laboratory procedures. The pH, bulk density, dispersibility, water absorption index, oil absorption capacity and emulsion capacity ranged from 5.77 to 6.65, 0.66 to 0.76g/ml, 16.67 to 50.33%, 135.47 to 189.87%, 118.33 to 136.67%, and 43.00 to 50.67%, respectively. The effect of variety and drying methods on these parameters was significant ($P < 0.05$) except for water-binding capacity and foaming capacity. There were also significant differences in the effect of drying methods and variety on the particle size distribution ($P < 0.05$) of the flours. The study showed that variety and drying method significantly affected the functional properties of trifoliolate yam flour. The data on functional properties of the flour reported will serve as useful baseline information for breeders and commercial utilization of trifoliolate yam flour for food and non-food purposes.

Nutritional composition and stability of *Saba senegalensis* fruit extract

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Saba senegalensis is an indigenous tree of Africa and is commonly found in the three Northern Regions of Ghana. Saba fruits are eaten as an appetiser while the leaves and bark of trees are used as medicine. The beverage industry is the largest user of fruit juice and absorbs over 80% of production. The main objective of the study was to assess the stability of fruit juice extract from Saba. Fruit samples of Saba were collected from the Nadowli District of the Upper West Region for juice extraction, proximate analysis, consumer acceptance and storage of the juice. Proximate analyses were carried out following the recommended methods of the association of official analytical chemists, and all analysed parameters were in triplicate. Consumer acceptance assessment was with a panel sample size of twenty. Mean values of the proximate composition in percentage were: crude fat (6.2 ± 0.00), crude protein (0.8 ± 0.02), ash (2.0 ± 0.03), carbohydrate (50.0 ± 0.01), moisture content (29.0 ± 0.01) and fibre (12.0 ± 0.10). Consumers showed a level of acceptance for the fruit extract. At a pasteurization temperature of 65°C for ten minutes, the fruit juice was heat-treated. The cooled fruit juice was successfully stored at 4°C for 22 days without fermentation. From the results, fruit extracts could be processed for commercial use based on the nutrient composition and consumer acceptance which would influence the domestication and further utilization of the plant.

Keywords: *Saba senegalensis*, nutrient composition, consumer acceptance, fruit extract

Upgrading value chains of neglected and underutilized species: promoting the processing and commercialization of baobab (*Adansonia digitata*) in the Upper East Region of Ghana

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A Non-Timber Forest Product (NTFP) is any commodity obtained from the forest that does not necessitate harvesting trees. It includes game animals, fur-bearers, nuts, seeds, berries, mushrooms, oils, foliage, medicinal plants, peat, fuel wood, forage, etc. People and animals around the world rely on these products for their survival and well being and income generation. Ghana with her diverse ecosystem possesses a large number of NTFPs that are being exploited. In the Upper East Region of Ghana and the Sahel savannah region of Ghana, one of the main resources for NTFPs is the Baobab tree. Despite its exploitation in other neighbouring countries for food and income generation, this tree has been largely neglected in Ghana. TREE AID, a UK charity, SNV and Partners, developed a project for the promotion of trade in NTFPs in the North of Ghana and Baobab was identified as one of the resources. After less than two years, the stakeholders have yielded more than two hundred thousand GHS from commercializing semi-processed baobab products and processed products are consumed and sold in local schools and markets in the Kassena & Nabdam districts. Currently, over 400 women from ten communities have been encouraged to organise themselves into 25 enterprise units. The project undertook studies, sensitization, training and capacity building for these groups. The groups received training in group dynamics and in processing of the fruits to obtain powder and seed, and further processing the powder into finished products and the seed for producing high value oil. For marketing, the project linked them to small/medium enterprises involved in the export of NTFPs abroad. Initial results have been very good, marketing transactions worth more than 200,000 GHS have been undertaken, and processed products are consumed and sold in local schools and markets in the Kassena & Nabdam districts and beyond. Initial positive impacts are conspicuous, jobs and income have been generated, nutrition improved and the Baobab is regaining the respect it once commanded.

Keywords: NTFPs, Baobab tree, processing, commercialization, income generation

Traditional baobab novel foods from Benin: processing, preservation and gender analysis

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The baobab, *Adansonia digitata*, is used by local populations in Africa on a daily basis for food and medicinal purposes. The leaves, the fruit containing its pulp, seeds and kernels are all used for food purposes and significantly contribute to food security. A survey performed in the rural areas of Benin on indigenous knowledge relating to processing and preservation of baobab provided data on the importance of baobab food products and their preservation according to socio-cultural groups and gender. Interviews were held with 223 women and 30 men belonging to 15 ethnic groups, in the age range 15 - 82 years and mostly with no or limited education. Correspondence analysis showed that the food use of baobab parts varies among ethnic groups. Most ethnic groups have similar opinions about the difficulty of certain processing operations. Apart from fruit breaking which is performed by both men and women, most of the difficult processing operations namely seed decortication, grinding and sieving operations for product recovery are performed exclusively by women. Women take care of all activities related to storage and preservation of kernels and fruit pulp. Because the pulp changes colour during storage, a storage experiment was performed to understand the phenomenon. It showed that colour change during storage is accompanied by vitamin C degradation and that loss of quality was accelerated by increasing temperature, water activity and storage time. Storage techniques that are compatible with local and women's conditions are suggested.

Keywords: Baobab food uses, processing and preservation, socio-cultural groups, storage

Developing a value chain for dabai: an underutilized fruit of Sarawak, East Malaysia

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Underutilized species play a significant role in current farming practices and lifestyle strategies of indigenous groups living in Sarawak, East Malaysia. Dabai (*Canarium odontophyllum* Miq.) is one of the popular underutilized fruits of Sarawak which has an enormous potential to contribute significantly towards food and nutritional security. The size of the fruit varies from 3.0-4.0 cm long and 2.2-3.0 cm in diameter, and weight 10.0-18.0 g. The purple skin and pale yellow fleshy pulp of fruit (3.0-5.0 mm thick) is edible, while the seed is discarded. Usually, after soaking for a few minutes, the fruit becomes softer and is very creamy when eaten. Besides having appreciable levels of minerals such as potassium (352 mg/100 g), phosphorus (65 mg/100 g), calcium (200 mg/100 g) and magnesium (106 mg/100 g), the fruit also contains high levels of protein (3.8%), carbohydrate (22.1%) and fat (26.2%). The fat contents are significantly higher than avocado (25%) and the olive fruit (23%). However, considerable barriers exist to unlock the full potential of this crop to support food security in this region. These include short shelf-life (only 2 days) and a poorly structured supply chain system. What is needed therefore are methods by which scientists can work with producers to identify specific value chain bottlenecks and deliver just-in-time research which can support the use of this fruit in strategies for balanced economic, nutritional and social development. This paper illustrates how a research value chain approach can assist local communities and smallholder farmers to make more effective use of Dabai in enhancing their income and nutritional wellbeing.

Keywords: food and nutritional wellbeing, underutilized fruit, shelf life, supply chain

Inclusive PPP-business model for developing underutilized plants to improve food security in Zimbabwe

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The program “Inclusive PPP-Business Model for Developing Underutilized Plants to Improve Food Security in Zimbabwe” is a 3-year public-private partnership between an international NGO (HWA - Hilfswerk Austria International), a local research organization (BIZ – Bio-Innovation Zimbabwe) and a private company (KAITE Pvt Ltd) which is funded by USAID and EuropeAid. The programme aims to commercialize a number of underutilized plants for which significant potential market opportunities exist for the global food, cosmetics and pharmaceutical industry in order to provide proof-of-concept, and to demonstrate the opportunities that underutilized plants hold out for smallholder farmers in dryland areas of Zimbabwe. The programme focuses on 10 underutilized species (Baobab, Devil’s Claw, Zambezi Tail Flower, *Acacia karroo*, *Lippia javanica*, Resurrection bush, Marula, Amaranth, Cassava and *Ziziphus mauritiana*). It includes research on the species, market and product development, organizing the smallholder production chain, attaining organic and fair trade certification as well as knowledge dissemination. HWA is responsible for the overall programme management, BIZ is carrying out market and product development, and KAITE is training the wild collectors on sustainable harvesting and processing of the plants, buying from the collectors and exporting it to European markets. Since its inception in 2012, the programme has already shown some major achievements: 3,000 wild collectors are involved in the value chain, the household income from wild collectors has risen from 30USD per month to 113USD, three species have been pushed to commercialization, five new companies were formed in Zimbabwe around those species, organic certification has been achieved and fair trade certification will be by the end of 2013. Eighty per cent of all registered wild collectors are women. This programme can serve as a model for many other species and many other countries for developing and marketing niche products from underutilized species, offering alternative household incomes to dryland areas, empowering women and girls, forming innovative public-private partnerships as well as climate change and mitigation.

Keywords: public-private-partnership, underutilized plants, wild collection, smallholder farmer

Agroforestry contribution to household livelihoods: evidence from farmer-managed natural generation in four countries in the Sahelian and Sudanian ecozones of the West African Sahel

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Rural communities in Africa are on the frontlines of climate hazards, due to their natural resource-dependent and climate-sensitive livelihoods. Many authors have highlighted the importance and use of woodland resources in spreading the risk associated with the availability of food over critical periods. In assessing the impact of farmer-managed natural regeneration (FMNR) on livelihoods, this study aims to provide insight into two different questions related to economic benefits and variation in these benefits across different contexts based on cross-sectional data collected from a stratified sample of 1,080 households in Burkina Faso, Mali, Niger and Senegal. The results indicate that the practice of actively managing and protecting non-planted trees and shrubs with the goal of increasing the value or quantity of woody vegetation on farmland have positive and significant effects on food security as well as a few significant effects among some other outcomes of interest including crop production, household assets and incomes. Thus, FMNR has a significant effect on overall household cereal production and food security. FMNR increases income from tree products in certain areas where markets for products are functioning well. It is estimated that basic fruit, pod, leaf and wood tree products harvested by households are valued at about slightly above \$200 per household in Mali and Niger. It was also noted that FMNR is practiced to some degree by nearly all households. FMNR as practiced is different in intensity and species in different countries and regions. The type of parkland system that contributes the most benefits also differs for different countries.

Keywords: agroforestry, impact, livelihoods, natural regeneration, parklands, Sahel

Improving opportunities for women in the value chains of underutilized species in Oyo State, Nigeria

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This study was conducted in the savanna zone of Oyo State, Nigeria to assess the roles played by women and the benefits they obtain from their involvement in the value chains of two underutilized species, *Vitellaria paradoxa* and *Parkia biglobosa*. The respondents in the study were women who are involved in value addition of the underutilized species. Three Local Government Areas (LGAs) were purposively selected in the derived savanna zone of the State, while five communities were selected from each of the three LGAs making 15 study sites in all. Ten respondents were sampled in each of the study sites making a total number of 150 respondents. Primary data were generated mainly from pre-tested structured questionnaires, and focus group and field observations. Women perform a variety of functions at different stages in the value chains of these underutilized crops, but their roles tend to be poorly visible and inadequately acknowledged. This is because they are either operating in the informal sector, are part-time employees, or carry out their activities at home between family responsibilities. Where women's roles are more prominent is primarily due to gender-orientated interventions by external agencies. Several opportunities and constraints to fostering women's empowerment in underutilized species value chain systems were identified and analysed. In conclusion, the study recommends provision of appropriate processing and preservation facilities, organization of skills upgrading programmes for value addition, packaging, construction of rural road networks and plantation establishment of the underutilized species.

Keywords: underutilized species, gender, value chains, *Vitellaria paradoxa*, *Parkia biglobosa*

More than chocolate: diversifying cocoa agroforests for higher profitability in Cameroon

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Cocoa (*Theobroma cacao* Linn.) is one of the main tree-based systems in West and Central Africa. Due to fluctuating prices, farmers have been trying to diversify this system for more sustained income. Since 1998, a tree domestication programme has helped farmers in the Central region of Cameroon to diversify their cocoa plantations through participatory tree domestication. This paper seeks to evaluate the financial profitability of cocoa agroforests by comparing traditional systems with enriched systems, and to determine the optimal mix of trees that allow maximum profitability. Some indigenous tree species, *Dacryodes edulis* (safou), *Ricinodendron heudelotii* (njansang) and *Irvingia gabonensis* (bush mango) were considered based on their prevalence in the study area, market potential and farmers' preferences. After interviews with resource persons to determine yields and prices of cocoa and associated trees, an ex-ante profitability analysis and an optimization and sensitivity analysis using GAMS 21.3 were carried out. The results show that the traditional system was not profitable and that only the enriched systems had an acceptable Net Present Value (NPV). The cocoa agroforest enriched with safou, bush mango and njansang had the highest NPV. Except cocoa only, all enriched systems had internal rates of returns close to 49% and so were profitable. Nevertheless, with the payback period, the cocoa+safou+mango+njansang system is the best, since capital invested was recovered after five years. The optimal use of resources in this agroforest showed that 713 seedlings of cocoa, 35 safou, 42 mango and 10 njansang trees per ha are sufficient to obtain a profit of 3,082,171 FCFA ha⁻¹ (6,850 USD). To conclude, cocoa-based agroforests are only profitable when other tree species are associated. The cocoa+safou+mango+njansang system is the most interesting combination and allows efficient use of resources. However, there is a need to test these data on-farm and do similar studies with other species.

Keywords: cocoa, agroforest, diversification, profitability

Evaluation of consumer preference for indigenous leafy vegetables in selected districts of Malawi

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Indigenous leafy vegetables (ILVs) have long been regarded as minor crops and thus have attracted little marketing attention compared to major crops and cash crops. However, ILVs are highly nutritious, have short production cycles, do not require many inputs like fertilizers and pesticides and they are adaptable to local growing conditions. As such, they can support smallholder farmers both in terms of subsistence and income generation without requiring large capital investment. Despite the potential that production of ILVs has, there has been little dissemination of information with regard to consumer preference. A study to evaluate consumers' market preferences for indigenous vegetables would assist smallholder farmers in planning for future production and seed multiplication programmes. The study was carried out in the Karonga and Lilongwe districts of Malawi. It was found out that popular vegetables include but are not limited to: amaranth (*Amaranthus* spp.), cowpea leaves (*Vigna* spp.), black jack (*Bidens pilosa*), spider plant (*Cleome* spp.), sweet potato leaves (*Ipomoea* spp.), pumpkin leaves (*Cucurbita* spp.), jute mallow (*Corchorus* spp.), cassava leaves (*Manihot esculenta*). Among these popular ILVs, amaranth was the most preferred, more than 60% of the sampled population ranking it as first in both districts. However, for some ILVs ranking was area-dependent. Availability of information on consumers' preferences for ILVs would attract more people to engage in ILV production and marketing as there is potential demand for these vegetables.

Keywords: indigenous leafy vegetables, preference, consumers

Marketing underutilized species: the strategy of Bioversity International

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Markets have been traditionally acting against biodiversity as their focus on few crops and varieties has been driven by the need for more 'convenient' food, products more responsive to commercialization needs and crops that better meet quality standards in markets. A closer analysis shows that markets can also play a supportive role for crop diversity, but such a contribution has been poorly explored and valorized. The research is very limited on how markets could leverage the multiple livelihood benefits (social, economic, nutritional) from agrobiodiversity as opposed to research that focuses just on economic gains. Bioversity's work in the area of marketing diversity tries to fill that gap through i) a better understanding of existing linkages between agro-biodiversity, nutrition and markets, ii) by exploring how these linkages can be best harnessed for making the most out of underutilized species and varieties and iii) by developing scaled-up and scaled-out market-driven interventions for supporting conservation-through-use of agro-biodiversity most effectively. Our agenda will contribute to the strengthening of the scientific capacity of NARS in tackling multi-disciplinary value chain R&D approaches within a livelihood framework. Our work will generate manuals and guides for NGOs, private sector companies, development agencies, extension services, business support organizations and farmer organizations that will show how to successfully explore the market potential of target crops through a set of novel approaches, methods and tools. Such products will target especially smallholder farmers and other value chain actors living in marginalized, albeit hotspot diversity areas, crafted in ways that are gender, nutrition and ethnically sensitive. Other key outputs will include simple participatory screening methods for commercially valuable traits to evaluate the market potential of agro-biodiversity. Overall, we shall contribute to better understand how agro-biodiversity can be mobilized through market interventions to generate income for the poor and at the same time contribute to positive nutrition and health outcomes.

Keywords: marketing diversity, multi-purpose value chains, conservation-through-use, neglected and underutilized species, nutrition

Contract farming by traditional African leafy vegetable seed producers in Tanzania: implications for household cropping income

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Traditional African leafy vegetables typically have been considered minor crops and have attracted little marketing attention compared to major crops such as maize and cash crops such as tomato and banana. Although demand for traditional African leafy vegetables has increased in recent years, the vegetable supply currently cannot meet demand due to a lack of quality seed of preferred varieties. To address this bottleneck in seed availability, it is important to understand the structure of the marketing system for traditional African leafy vegetable seeds and to develop strategies to improve the system. Evidence suggests that contract farming is an efficient mode of integrating smallholder farmers into the agricultural marketing chain. We examined the determinants of traditional African leafy vegetable seed producers' participation in contract farming systems and sought to identify the impact of contract farming on seed producers' income. A primary survey of 90 farm households producing traditional vegetable crop seeds in the Arusha, Tanga, Morogoro, Dar es Salaam and Dodoma regions of Tanzania were surveyed using a systematic random sampling approach. Among 90 farm households, 16 farm households participated in contract farming systems. Out of the 16 farm households, 9 were headed by women. On average, income from crop sales per season was USD 163 per household. However, contract farmers received a higher crop income per season (USD 418) than non-contract farmers (USD 124). We tested the following hypotheses using Hackman's two-stage approach: 1) gender plays a positive and significant role in participation of households in the contract farming system, and 2) small-scale farmers receive higher income from crop sales than large-scale farmers. Policy options to improve marketing systems for seed producers and growers of traditional African leafy vegetable crops are discussed.

Keywords: contract farming, market participation, traditional African leafy vegetable seeds, crop income

Exploring and expressing the potential of geographical indications

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Developed countries are rich in biodiversity, and a number of attractive native products are traditionally derived from domesticated and wild plants and animals, often belonging to the so-called Neglected and Underutilized Species (NUS). In some cases, such products have shown potential in domestic and export markets, but original quality reputations are at risk from unfair competition, poor quality management and insufficient understanding as to how genetic, location-specific and management factors influence product quality. geographical indications (GIs) are a tool to overcome some of the limitations faced by traditional local products in markets. In particular, they can provide protection for products from the place of origin and the traditional knowledge associated with them to combat any wrongful use of their name which could be damaging to a product's reputation. Their implementation could therefore bring about considerable benefits for poor agricultural communities. The paper describes a scoping process in some target countries in Africa and Asia in which traditional and possibly indigenous biodiversity candidate products for GI protection are identified. The potential for income generation for local communities, particularly women, through marketing of the products defined by their geographical indication are assessed as well as the challenges communities and value chains face in setting up GI quality management systems. Furthermore, the legal implications of GI registration that underpin the improvement of national regulatory frameworks on Geographical Indications in those countries are explored. Finally, the paper is making an innovative link between the GI schemes and the IPR/Access and Benefit sharing schemes with benefit being income generation as well as other socio-economic dimensions that pertain to identity and genetic resources.

Theme 3: Creating an enabling policy environment

Policy interventions are crucial for creating an enabling environment that leads to enhanced utilization of NUS species. Abstracts under Theme 3 present policy issues that may promote or hinder the expanded use of NUS in Africa. Contributions cover both national and international policy, as a basis for recommending actions that support the promotion of NUS. A number of abstracts cover capacity development and institutional aspects for effective research and development, and better use of NUS in Africa. Partnerships and innovation platforms for participatory, multi-stakeholder development of NUS are also discussed.

Information for smallholders in Africa

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The Food Plants International database of edible plants of the world has increasingly focused on Africa as a region of food insecurity and under-nutrition. It is a continent that is rich in underutilized species and traditional knowledge but this is often not widely accessible. The database currently contains information on 26,350 edible species for the whole world. Of these, 7,300 species are currently known to be growing in Africa. The information has been written in easy-to-understand English and can, for example, be searched for food plants suitable for arid zones in Africa (1,574 species). This is one of the most vulnerable sectors of Africa. Increasingly, information is being added to highlight food plants that can be processed and stored for use during the dry season. Where available, nutritional information is included. In this presentation, the focus will be on using the database information to deliver appropriate information for any country or region in Africa. Selecting plants on an agro-ecological basis with close attention to nutrition has the potential to ameliorate food shortage, malnutrition and develop capacity to cope with climate change. The global scope of the database offers unique features where information available for another region or a related species can be adapted and applied to African locations. Although an older version of the database is available for perusal on our website (www.foodplantsinternational.com), using the database from a DVD or on the computer hard-drive is much faster and easier. Copies will be made available at the conference. These are covered with a Creative Commons copyright allowing them to be copied and distributed freely.

An assessment of technical, economic and social gaps and information needs for smallholder farmers in the practice of ecological organic agriculture in Kenya

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Food security is an issue of great and growing concern in many countries especially in Africa. Despite global pledges, a number of reports continue to indicate that the number of people suffering from hunger has continued to increase every year. Kenya, like many other sub-Saharan countries faces a fundamental food security challenge. Despite steadily falling fertility rates and family sizes in the country, the population continues to increase and so in parallel is the demand for food. Feeding the over 40 million people in the country will require a wide range of creative, sustainable agricultural systems which not only provides food but also factors in the economic value of nature-based services such as forests, wetlands and soil organisms that underpin agriculture. Simply applying the “industrial” agricultural models of the twentieth century into the twenty first century as a single solution to the agricultural production challenges will not work. It is acknowledged that ecological organic agriculture can contribute to socio-economic and ecologically sustainable development, especially in poorer countries. It can increase agricultural productivity and raise incomes at low cost using locally available technologies, without causing environmental damage. It is against this background that this study aimed to establish the information needs, as well as the knowledge smallholder farmers in Kenya have of ecological organic agriculture. The study revealed that the smallholder farmers in Kenya grow a wide variety of crops on their farms, which may comprise a valuable combination in the application of ecological organic agriculture strategies, especially with respect to controlling pests and diseases. Despite the wide diversity, the farmers showed little knowledge of the potential of such diversity in controlling pests and diseases and their role in soil amendments. The study recommends innovative ways and means to introduce and reinforce ecological organic agriculture already inbuilt in current smallholder farmer practices.

Keywords: ecological organic agriculture, food security, information needs, smallholder farmers

Public-private partnerships in tree domestication for sustainable agriculture and business innovations: *Allanblackia* species as a case study

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Trees play a crucial role in almost all terrestrial ecosystems and provide a range of products and services to rural and urban people. As natural vegetation is cleared for agriculture and other types of development, the benefits that trees provide are best sustained by integrating trees into agriculturally productive landscapes - a practice known as agroforestry. Tree domestication is an indispensable process in agroforestry for provision of the required tree genetic materials to meet the desired objectives and provide high-value products. In particular, domestication of new tree crops, often termed as “neglected and underutilized crops” is one of the means for improving food and nutritional security in sub-Saharan Africa. In the last decade, a participatory tree domestication approach involving close collaboration of scientists, government institutions, investors, NGOs and farmers has been developed for the edible oil-producing *Allanblackia* species of the family Clusiaceae in West, Central and East African regions. The approach, being practised in mixed agroforestry regimes is enhancing diversification of species, incomes and rural business development. This paper highlights the achievements made in the domestication of *Allanblackia* species and the need for better engagement of public and private partners in future agricultural innovations.

Keywords: agroforestry, participatory tree domestication, underutilized crops, species diversity

Determinants of the cultivation of selected neglected and underutilized species by small-scale farming households in the Nigerian Guinea Savannah

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There appears to be an increasing consensus that diversifying into the cultivation of 'Neglected and Underutilized Species' (NUS), in addition to raising conventional crops, offers a plethora of livelihood-enhancing benefits to small-scale agricultural households. However, the degree of diversification into these crops by farmers may be premised on the availability of certain household and farm-specific variables the specific nature of which should be understood before personalized recommendations are proffered. This study therefore examined the determinants of small-scale agricultural households' diversification into the cultivation of cashew nut plant (*Anacardium occidentale*), *Moringa oleifera* and *Jatropha curcas* in the guinea savannah region of Nigeria. Kwara state in Nigeria was purposely selected as the study area and data were generated from 150 randomly sampled small-scale farmers through the use of a questionnaire. The determinants of the degree of diversification was modelled with a Tobit regression model. Findings indicate that respondents diversified more into the cultivation of cashew (70.9%), followed by *Moringa* (38.4%), and *Jatropha* (11.3%) respectively. Degree of diversification was positively influenced by farm size ($P<0.01$), level of education of household head ($P<0.01$), membership of cooperative ($P<0.01$), income from farming ($P<0.05$), and was negatively influenced by the land tenure system practised ($P<0.05$). Findings imply that small-scale farming households may avoid diversification into these crops if they lack land tenure security and limited access to farmland. This study therefore advocates amongst others, an equitable access to farmland through a structural and legislative land tenure reform policy.

Keywords: land tenure, non-mandate crops and diversification index.

Socio-economic contributions of neglected and underutilized species to livelihood security in rural southwest Nigeria: *Thaumatococcus danielli* as a test case

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There is no gainsaying the fact that Nigeria is blessed with vast human and material resources. Despite this, it is very appalling to know that a sizeable number of inhabitants of the country have continued to face untold hardship arising from dwindling incomes, rising poverty levels and other forms of socio-economic deprivations. This is not unconnected with inadequacy of information and lack of awareness on and accessibility to livelihood-enhancing opportunities available in different regions of the country. The results presented here relied on data collected from a random sample of 320 households engaged in the production, processing and marketing of *Thaumatococcus danielli* from three communities in rural Southwest Nigeria. Data analysis revealed the average age of respondents to be 63 years with a mean household size of 7. Distribution of respondents by educational level showed that only about one-quarter had tertiary education with more females engaged in the processing and marketing of *Thaumatococcus danielli* products. On the economic contributions of this crop to livelihood security of respondents, about two-thirds (68.3 percent) of them are engaged in the production, processing and marketing of this particular NUS either on a full-time or part-time basis thereby depicting its relative importance to other income-generating activities/ventures in the study area. In fact, a further analysis of the data revealed that the income generated from *Thaumatococcus danielli* amounted to between 57-73 percent of the total income of respondents harnessing it. However regarding the determinants of harnessing *Thaumatococcus danielli* as a source of livelihood, age ($P<0.05$), gender ($P<0.00$), educational status ($P<0.01$), poverty status ($P<0.05$), participation in off-farm activity ($P<0.05$), extension contact ($P<0.00$) and access to markets ($P<0.10$) were very significant. While the coefficients of educational status, poverty status and extension contact were negative, those of age, gender, access to market were positive. It is therefore suggested that effort should be geared to building the capacity of respondents through education to enhance their earning potentials and adoption of new skills. Awareness should be created on the untapped livelihood-enhancing opportunities available in the study area so as to enhance the income of residents and reduce poverty.

Keywords: income, livelihood, NUS, Southwest Nigeria, *Thaumatococcus danielli*

Prospects and challenges for preserving and mainstreaming underutilized traditional African vegetables

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Traditional African vegetables are sources of food and nutrition diversity and can generate substantial income to alleviate poverty in sub-Saharan Africa. Traditional green leafy and fruit vegetables have been part of local food systems in the region, and the diversity currently available can be largely attributed to farmers' conservation and selection efforts. The diversity of traditional vegetables and other neglected and underutilized plant species is threatened by many factors such as population pressure and expansion of land under staple crops. As younger generations migrate to cities, fewer people remain in rural areas to take up farming and conserve traditional crops. A considerable number of accessions have been collected from various countries in sub-Saharan Africa, regenerated, characterized, and stored for the short and long term. Pertinent information on each accession has been made available online. Collection and characterization efforts should continue to fill gaps in existing collections and to preserve this valuable diversity. The use of modern scientific tools significantly enhances the preservation and utilization of traditional vegetables. Existing accessions have been used for breeding research, resulting in the development of many breeding lines and the release of improved cultivars in Africa. Quality seed of purified accessions, breeding lines and improved cultivars has been distributed across Africa and other parts of the world for use in breeding and other research and development programmes. Prospects and challenges facing conservation, technology generation and utilization of available technologies are described in this paper.

Keywords: conservation; germplasm development; improved cultivars; selection; traditional vegetables

Current policy issues and recommendations for sustainable management of non-timber forest products in the northern savannah zones of Ghana

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The Northern Savannah Zones of Ghana abounds in numerous non-timber forest products (NTFPs) that have played a critical role in sustaining rural livelihoods for generations. However, over the years the exploitation of NTFPs has been subjected to poor management resulting in unsustainable harvesting, and inequitable benefit distribution that has led to gradual but evident destruction of biodiversity of critical importance in sustaining rural livelihoods and food chains over the long term. Recent threats to the NTFP sub-sector include expansion in plantation agriculture, illegal exploitation of timber and illegal mining in Northern Ghana. In 2012, a study was conducted to understand the appropriateness of the existing forest policy environment for the sustainable management and utilization of NTFPs in the Northern Savannah Zones of Ghana. This paper explores current policy and institutional issues relating to the exploitation of NTFPs within the context of both formal and informal natural resource governance. The study involved extensive literature reviews, focus group discussions, key informant interviews and stakeholder analysis. The study revealed that there is a general consensus among stakeholders regarding the inadequacy of the current forest management policy in the long-term sustainable exploitation of the NTFPs in Northern Ghana.

Keywords: Non-Timber Forest Products, livelihoods, policy, governance, management

Thousands of crops and very little money – how can marker technology be applied to underutilized species?

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Many underutilized species have had limited conventional breeding work and many still exist as landraces. Given the substantial progress made in enhancing yields in major crops (e.g. four-fold in 100 years in UK wheat and Malaysian oil palm), it seems likely that current low yields are not an intrinsic limitation to improvement in the future. Molecular markers have the potential to increase the rates of genetic improvement in underutilized species, but their development and application has a cost, both in terms of the consumables used and also the physical and human infrastructure required. In addition, are the targets for marker-assisted selection always the same for major and for underutilized crops? Some may be common, such as disease resistance/tolerance. However, there is evidence that a landrace structure involving multiple genotypes (which have been adapted to a particular environment through continuous exposure) could be more resilient to environmental instability. In this paper, we discuss what capacity and tools need to be developed within underutilized crop species and how many can be adopted from related species. We further consider the issue of how much of that capacity needs to be 'in-house' and how much can be outsourced effectively to a service provider? This paper explores some of these questions in relation to on-going work on Bambara groundnut and other legumes.

Keywords: molecular markers, marker-assisted selection (MAS), genetic improvement, breeding

Innovation for diversification: Crops for the Future, Crops for the Future Research Centre and the creation of an underutilized species knowledge network

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Crops for the Future (CFF) and its research arm, Crops for the Future Research Centre (CFFRC), deal with the challenges of raising awareness and undertaking research on underutilized species. This includes the technical challenges associated with assembling and disseminating information and undertaking new research. It also involves overcoming socio-cultural barriers regarding underutilized species. In this paper, the progress of each organization in meeting these challenges is outlined. Both organizations face challenges not encountered by those engaged in research into major crops, the latter being undertaken in a context where established socio-technical networks exist for these crops. These networks can be very complex linking widely distributed global networks of researchers, producers, distributors and consumers. They incorporate a considerable body of existing knowledge concerning these crops and clear understanding among stakeholders about their uses and values. By contrast, underutilized species may possess socio-cultural significance in local food networks. However, there is typically limited knowledge, demand, or socio-economic infrastructure to support their wider production. The nature of underutilized crop networks influences the development of both CFF's and CFFRC's programmes. Rather than replicating the development of research into the major crops, the challenge has been to develop a new approach that integrates different forms of knowledge into initiatives aimed at delivering practical benefits employing limited resources. Thought thus needs to be given to the context in which scientific knowledge is generated and the non-scientific validation to which it is subject. Both CFF and CFFRC have thus been required to develop a broader agenda considering how specific species are integrated into wider food systems. The paper demonstrates how the organizations have attempted to address this challenge through CFFRC's development of the value chain research approach and the advocacy work being undertaken by CFF.

Keywords: CFF, CFFRC, research value chain, awareness, advocacy

Enabling policies and practices for neglected and underutilized species (NUS): the case of aquatic food plants in Sri Lanka

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Sustainable practices backed by effective policies are a vital prerequisite to enable Neglected and Underutilized Species (NUS) utilization. Sri Lanka is a country with one of the highest inland water bodies and diverse aquatic habitats, which are not utilized. Fresh water bodies comprise around 260,000 ha. and seasonal tanks comprise 100,000 ha. and undergo serious water deficit every year. Seasonal tank cascade systems are highly vulnerable to climate change, threatening the livelihoods of people. Before opening the country's economy into an open market economic system in 1977, NUS utilization was satisfactory with import substitutive agriculture based on a closed economy. However, under an open-market economic regime, novel policy tools and practices are needed to mainstream aquatic NUS into the economy. The Ministry of Environment and Renewable Energy in Sri Lanka has launched a pioneering project for linking biodiversity, climate change and livelihoods. In this project, aquatic NUS of food value are identified, defined, quantified and valued using appropriate valuation techniques, and hence are mainstreamed into the national economic exchange by market and non-market means.

Identified aquatic NUS of food value are Lotus (*Nelumbo nucifera*), Water lily (*Nymphaea pubescens*), and Wavy sword plant (*Aponogeton crispus*). As a composite policy tool, participatory biodiversity management tools such as the seasonal aquatic food festival are proposed. Ways to improve the capacities of rural institutions like farmer organizations to operationalize a payments scheme for ecosystem services such as NUS were formulated

Keywords: aquatic food plants, enabling policies, aquatic food festival, payment for ecosystem services

Research capacity for neglected and underutilized species: a situation analysis in ten African countries

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In 2010 and 2012 more than 1300 scientists under 40 years of age from ten countries in sub-Saharan Africa applied to at least one of seven training courses undertaken in the ACP-EU project, "Building human and institutional capacity for enhancing the conservation and use of Neglected and Underutilized Species (NUS) of crops in West Africa, and Eastern/Southern Africa". This high demand for training indicated a significant body of on-going NUS research, but raised questions about availability and quality of training, mentoring and institutional support for such research. A survey was administered to 592 applicants in Benin, Ghana, Mali, Nigeria, Senegal, Ethiopia, Malawi, Mozambique, Kenya and Uganda. The survey elicited 383 responses from scientists between 24 and 57 years of age, of which 39% were women. Most respondents worked in a university/college (59%), or national research institute (29%) in a developing country. The majority held a masters degree (61%) or PhD (31%) in agriculture or a related field in the biophysical and social sciences. About half were studying for a higher degree. Most respondents were currently researching NUS or wanted to do so in the future. Working on legumes and pulses, cereals, leafy vegetables, and roots and tubers, amongst others, the top issue NUS researchers addressed was nutrition, followed by genetic diversity and its conservation, and economic aspects of production and marketing. Main constraints were lack of funding, lack of information or expertise, and lack of appreciation for these crops by the government and farmers. The support for NUS research was poor; policy support was ranked limited to average by most respondents. A large number of respondents' institutions included NUS in their strategies (68%), but access to mentorship on NUS was most commonly rated as poor to adequate. The survey revealed a strong interest and skill base for NUS research among African scientists. Increased opportunity for training, networking and funding as well as policy support would strengthen this emerging and important field of research.

Keywords: capacity development, training, mentoring, research capacity, policy support, West Africa, Eastern/Southern Africa

Part 2

Poster presentations

Theme 1: Resilience of agricultural and livelihood systems

1.1 Agronomy

Agronomic evaluation of thirty six African yam bean accessions (*Sphenostylis stenocarpa*) in south-eastern Nigeria

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African yam bean [AYB] (*Sphenostylis stenocarpa*) is a multi-purpose tropical legume but still remains underutilized. It produces edible seeds above ground and small edible tubers subterraneously. Thirty two accessions from IITA, three accessions from Benue State and accessions from Ondo State of Nigeria were evaluated at the University of Nigeria for their yield and yield components. Phenotypic variation of the germplasm was assessed with ANOVA and GGE biplot analyses. Phenotypic variations were significant ($P < 0.05$) for four growth and seven yield-related traits. GGE biplot analysis revealed that TSs 23, TSs 10, TSs 84, TSs 24, TSs 349, TSs 101, TSs 125, and TSs 49 had average performance across the traits evaluated. TSs 111, TSs 137, TSs 60, TSs 109, TSs 94, TSs 82, Sese Ondo and Ahuma Tseagbaragba displayed distinct phenotypic characteristics suggesting that these accessions could be promising parents for genetic improvement. TSs 60, TSs 89 and Ahuma Tseagbaragba were the best combiners for number of pods/plant, number of filled pods, total pod weight/plot, seed weight/plot suggesting that these accessions are the most adaptable to the derived savannah agro-ecology. GGE biplot identified total pod weight per plot as the most significant discriminatory trait for assessing phenotypic performance of African yam bean in the agro-ecology.

Keywords: accessions, yield, germplasm, *Sphenostylis stenocarpa*.

Growth and yield response of three sweet potato (*Ipomoea batatas* L.) varieties to different seasons of a subtropical environment of KwaZulu–Natal, South Africa

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Sweet potato is regarded as an important food security crop. In South Africa, it is predominantly grown by resource-poor subsistence farmers. Recently, breeding programmes are focusing on orange-fleshed varieties since they contain vitamin A and can thus help alleviate malnutrition. Since the crop is sensitive to temperature changes, there is a need to evaluate its adaptation to different seasons even within a climatic region. The objective of this study was to assess the agronomic and physiological performance of locally bred sweet potato varieties over different seasons in a subtropical region of KwaZulu-Natal, South Africa. Three varieties of sweet potato (A40, A45 and 199062.1) were grown in a randomized complete block design, replicated three times, during winter and summer of the 2012/13 season. Growth data included vine length, leaf number, stomatal conductance (SC) and chlorophyll content index (CCI), measured bi-weekly. At harvest, root yield and biomass were determined. Different varieties exhibited significantly different ($P < 0.05$) growth patterns (vine length, leaf number and branching habit) within a specific season, while physiological responses were affected by plant growth stage and varieties (CCI was higher in A45 and 199062.1 than A40; the opposite was true for SC). Biomass and storage root yield varied significantly ($P < 0.05$) between the two seasons. The summer season recorded 88% higher yield compared with the winter yield. In conclusion, growth, physiology and yield of sweet potato varieties varied with seasons. Varieties A45 and 199062.1 were shown to be more adapted to subtropical winter and summer conditions and tended to avoid drought stress by maintaining uniform chlorophyll content throughout the season than variety A40. Variety A40 produced higher yield in summer although not significantly different from the rest of the varieties.

Keywords: growth, yield, season, sweet potato.

Exploitation of wastewater disposal sites and river banks in the cultivation of *Vernonia* spp. (Ndolé) in urban areas in Cameroon

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Ndolé is one of most delicious dishes in the Central African region. Bitter leaf (*Vernonia*) is obtained from the leaves of a diminutive evergreen shrub, which grows throughout Africa. The genus *Vernonia* comprises roughly 1,000 species which belong to the Asteraceae family. A number of *Vernonia* species such as *V. amygdalina*, *V. calvoana* and *V. colorata*, are consumed in the form of vegetables. This plant is employed for treating various conditions such as fever, diabetes and a non-pharmaceutical solution has been developed to cure AIDS-related diseases. Though eaten by a large proportion of the population, cultivation is limited to the southern parts of Cameroon and mostly in the rainy season. In order to ensure availability in non-growing areas or seasons, the vegetable is usually processed and preserved. Processing and preservation methods used are thought to influence the nutrient content of these vegetables. Varied rainfall is a risk factor in the cultivation of this plant. It makes it impossible for vegetable crops to grow without proper irrigation. Rural-urban migration, aggravated by the adverse effects of climate change on rural farming, is thought to be one of the main reasons behind the growing number of urban farmers in the city who need land, and thus exploit the river banks and wastewater sites for farming. Wastewater irrigation provides the necessary plant nutrients, especially nitrogen and phosphorous. Farming in wastewater poses both health and environmental threats, not only to the urban agriculturalists, but also to the consumers of the crops grown on such fields. This water contains pathogenic organisms and disease vectors similar to those in human excreta. It is therefore important to properly prepare and also disinfect bitter leaf that is farmed in wastewater before consumption.

Keywords: cultivation, *Vernonia* spp., Ndolé, wastewater, food security

Evaluation of thirteen Bambara groundnut (*Vigna subterranea* (L) Verdc.) landraces under 12 h and 14 h photoperiods

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Variation in yields of bambara groundnut have been reported by several workers. These differences have been attributed amongst others to variations in photoperiod at different sowing dates within the same environment and between environments. Thirteen bambara groundnut landraces were evaluated at 12h:12h and 14h:10h, light:darkness at the Crop Science Department, University of Guelph, Canada. Sunshine mix LA4 was put in 78.4 gallons pot per growth chamber. Four grams of 20:20:20 N:P:K was added to each pot and thoroughly mixed with the soil. One walk-in growth chamber was used for each treatment. Each landrace was replicated in six pots. Growth chamber temperatures were maintained at 30°C day and 25°C night at a relative humidity of 60%. Growth chamber PAR ranged between 250-300 $\mu\text{mol m}^{-2} \text{s}^{-1}$. Days to seedling emergence were significantly less under 12h than 14h photoperiod ($P=0.02$). Days to flowering were significantly higher under 14h than 12h photoperiod. Five out of the 13 landraces; Burkina, Mottled Cream, Zebra Coloured, Tan One and Tan Two (both from Tanzania) podded under both 12h and 14h photoperiod. All but two of the landraces podded under a 12h photoperiod. Leaf area per plant, shoot dry weight per plant and root dry weight per plant were all higher under a 14h than a 12h photoperiod. Genotypes that produced pods under a 14h photoperiod were observed to be early maturing relative to the others. Morphologically, three plants of Tan One produced three, four and five leaflets on different petioles of the same plant instead of the well known trifoliate character of the crop. Landraces were identified for cultivation in the lower and higher latitudes especially in sub-Saharan Africa where long photoperiod greatly affects pod yield.

Keywords: Bambara groundnut, photoperiod, pod yield, daylength, Ghana, Tanzania, Burkina Faso

Effect of sowing date on the performance of Bambara groundnut (*Vigna subterranea* (L.) Verdc.) landraces in the transition and forest agro-ecologies of Ghana.

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Bambara groundnut is an underutilized and until lately, an under-researched crop. Its ability to produce some yield where other crops such as groundnut fail has been established. The balanced nutritional quality of the crop coupled with its resistance to drought makes it a crop of choice to achieve food security especially in the dry areas of Africa. Experiments were conducted in 2007 and 2008 in two agro-ecological zones of Ghana namely, Wenchi (transition) and Fumesua-Kumasi (forest) agro-ecologies to determine the effect of sowing dates on the yield of bambara groundnut landraces namely Burkina, NAV 4, NAV Red, Black eye, Tom, Mottled Red and Ada. Sowings were done in a factorial arrangement in a randomized complete block design with three replications. Pod yields ranged between 600 kg/ha to 5.5 t/ha and seed yields between 420 kg/ha to 3.8 t/ha for the various sowing dates. Pod yield of over 5 t/ha were produced by Burkina and Black eye. Harvest indices ranged from 0.12-0.53. Minor rainy season sowing of bambara groundnut produced more pod yield than major rainy season sowing. Tom was a highly vegetative landrace. Pod yield was higher in the transition than the forest agro-ecology. Where irrigation is available, sowing bambara groundnut just before the rains in February and March in the transition and forest agro-ecologies of Ghana produce high pod yields.

Keywords: Bambara groundnut, transition agro-ecology, landraces, sowing date

Finger millet (*Eleusine coracana*) yield estimation: integrating remote sensing and indigenous knowledge in Western Kenya

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Subsistence agriculture in Kenya is rain-fed, and in the era of global climate change, crop yield is unpredictable posing a great challenge to food security among the rural dwellers. Among farmers who grow finger millet (*Eleusine coracana*), there is a tendency to apply traditional skills, practices and technologies to boost the crop yield. However, these practices have been overlooked by national research and extension services and there is little documentation of the same. Today, remote sensing is being used to successfully predict crop yield. The question however is, can remote sensing show any change in crop vigour thereby enabling yield estimation based on farmers' traditional practices? This project is aimed at improving our understanding of the relationship between remote-sensed data, indigenous practices and crop vigour in order to predict and improve finger millet yield thereby promoting the cereal as a food security crop. A survey will be carried out to investigate farmers' indigenous knowledge and practices in finger millet growing areas. This will be followed by satellite image analysis of farms during the different stages of finger millet growth. Data collected will be regressed against finger millet yield in order to analyse the relationships among remote-sensed data, indigenous practices and crop yield. The project will document farmers' indigenous knowledge, as well as produce finger millet agronomic advisories.

Keywords: *Eleusine coracana*, remote sensing, indigenous knowledge

Improving rooting in leafy stem cuttings of *Allanblackia floribunda* Oliv. using fertilizers

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Stockplant management is essential for rapid rooting, high rooting success and a large number of roots in stem cuttings. This can be achieved through regular pruning of stockplants and application of fertilizers. *Allanblackia floribunda* is amenable to vegetative propagation through rooting of stem cuttings. However, rooting is both slow and limited to only a few roots, often a single lateral root which is very likely to result in both poor growth and instability as the tree grows taller. This study examines the effect of granular NPK 20-10-10 doses (0,25 and 50g/stem) applied to *A. floribunda* stockplants and the effect of foliar NPKs (15-15-30, 20-20-20 and 30-10-10) applied on stem cuttings in propagators at different physiological stages of cutting growth (setting, callus initiation and both) on their rooting ability. Stem cuttings rooting ability was not significantly ($P=0.81$) influenced by single dose application of granular NPK on stockplants. However, with three applications the difference was significant ($P=0.035$) with stems cuttings from stockplants treated at 50g, 25g and 0g per stem displaying $58\pm 3.5\%$, $45.89\pm 2.71\%$ and $30.85\pm 2.64\%$ of rooting respectively after 18 weeks. The number of roots per rooted cutting varied from one to three. Application of foliar fertilizer, NPK20-20-20 on stem cuttings at different physiological stages, significantly ($P=0.04$) boosted the rooting of stem cuttings after 24 weeks. The greatest rooting percentage was shown in NPK 20-20-20 at the callus stage only ($85.71\pm 4.1\%$) while the least was observed in NPK 30-10-10 (both stages, which means applied at setting and at callus initiation). The number of roots per cutting was not significantly different ($P=0.98$), however, cuttings treated to foliar NPK 20-20-20 (callus and both) and NPK 15-15-30 (both and at setting) displayed the highest tendency to develop three or four roots. The results of the study demonstrate that fertilizer application on stockplants and in the propagator has important implications on root formation in *A. floribunda*. However, there is a need to determine the optimum combination of both fertilizers and periods of application.

Keywords: fertilizer application, root number, stockplants, vegetative propagation

Laboratory evaluation of plant oils on egg viability, fecundity and mortality of cowpea weevil *Callosobruchus maculatus* Fabr. (Coleoptera: Bruchidae)

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Laboratory experiments were conducted to assess the effects of oil from the seeds of *Acacia nilotica*, *Balanites aegyptiaca* and *Senna occidentalis* and a synthetic insecticide phostoxin on cowpea weevil, *Callosobruchus maculatus* during storage. Oil was extracted using the Soxhlet extraction apparatus. Uninfested cowpea seeds were sterilized by freezing for three weeks and were used during experimentations. Insects were cultured in the Physiology Laboratory, Usmanu Danfodiyo University, Sokoto, Nigeria. Local varieties of cowpea called Dankalbaz and Dangidan Yunfa and IITA Striga-resistant variety (IT 97K-497-35) were used. Oil was measured into 1mL, 1.5mL and 2mL aliquots. This was admixed with 250g of the sterilized cowpea seeds. These were then infested with 10 pairs of newly emerged adult bruchids obtained from the culture. Phostoxin-treated samples had the highest mortality rate with all the introduced adults dying within 2 days and very few eggs were recorded. Mortality counts on oil treated cowpea ranged from 16.33 ± 0.57 (81.6%) - 20.00 ± 0.00 (100%). A similar trend was observed for fecundity and egg viability. It was also discovered that the efficacy of the extracts in all the parameters observed increases with increase in concentration.

Keywords: *Callosobruchus maculatus*, plant oil, phostoxin, fecundity, viability

Crop-Innovations: a charity providing demand-driven seed research in underutilized species

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Improved exploitation of underutilized species is, in part, constrained by difficulties with seed production and quality. In particular, factors including seed size, efficient seed set, seed germination, storage conditions and nutritional content are issues that inhibit further utilization of a species. Crop-Innovations provides research capabilities and expertise to understand the cause of a specific seed problem. Our organization can then coordinate activities to resolve the problem and work to provide improved seed that will enhance utilization of the crop. This is achieved by building networks of researchers and managing collaborations. Our staff can work directly on the species of interest, or research can, initially, be conducted in model systems and knowledge transferred to the crop. For example, current research on *Arabidopsis* has identified a small number of genes that play a key role in regulating seed size. Homologues have been identified in crop plants and the discoveries are being applied to improve yields. Crop-Innovations can assist with finding funding sources and writing applications for funding. Previous and on-going projects that aim to improve seed quality of underutilized species will be presented and discussed.

Keywords: seeds, research co-ordination

***In vitro* propagation of *Trichosanthes cucumerina* L. (snake tomato).**

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Trichosanthes cucumerina commonly known as snake tomato is an important crop species common to sub-Saharan Africa but has not gained widespread use. Recently, there has been increasing attention on the crop in several parts of Africa because of its red fruit pulp that serves as a substitute for tomato sauce. It contains proteins, fat, fibre, carbohydrates, vitamins A and E. This study aimed to regenerate pure lines of snake tomato for *in vitro* mass propagation with the objective of providing an alternative to the common tomato thus enhancing food availability. The most suitable combination of plant growth regulators for the *in vitro* propagation of *T. cucumerina* was evaluated. Nodal cuttings from *in vitro* regenerated plantlets were cultured on Murashige and Skoog (MS) fortified with different concentrations of cytokinins and also on MS fortified with coconut water. The best results for axillary shoot formation (mean number axillary shoots per plantlet, 7.0 ± 0.57) and root length (4.6 ± 0.30 cm) were recorded for 0.1mg of indole-3-butyric acid. No significant difference ($P > 0.05$) was observed for nodal number at concentrations of 0.1mg and 0.15mg/L benzyl amino purine (BA). Generally BA was superior in proliferation capacity as compared to kinetin or BA in combination with kinetin. Poorly developed roots or no rooting was observed on almost all the media enriched with a combination of both BA and kinetin. On MS fortified with different concentrations of coconut water, the best mean results for axillary shoots (3.4), nodal number (10), and root number (4) were recorded on 30% coconut water, while shoot length was highest on 40% coconut water. This procedure can be replicated on several other similar neglected species with minor modifications in order to enhance food security and reduce hunger.

Keywords: *Trichosanthes cucumerina*, food security, mass propagation

Design and technical performance of a capillary irrigation system to produce neglected and underutilized vegetables

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Capillary irrigation is the most recently developed method of existing irrigation systems. We have designed and studied the performance of two prototypes of this system. The first intended for domestic production of vegetable crops was tested on *Amaranthus cruensus* L. The second for nursery production of seedlings was tested on *Moringa oleifera* L. The systems had an irrigated area of 45cm x 23cm (1035cm²) consisting of a soil chamber, a water reservoir, capillary chambers and a water level control system. They were compared to ordinary irrigation (watering cans). The experimental design was a split-plot consisting of two main plots - ordinary irrigation system (OS) and capillary irrigation system (CS) randomly. The number of leaves, plant height and root collar diameter (with a digital caliper) were measured. The amounts of water supplied and lost (drainage) were measured with graduated plastic cans and soil humidity and density were measured by gravimetric methods. The data were analysed with R software. The results showed that amaranth plants grown under CS developed more leaves, greater height and diameter than the OS. For amaranth, in terms of yield, the CS produced almost a four times higher yield (4.21 kg/m²) than the OS (1.12kg/m²). The *Moringa* seedlings showed the same performance in both systems. A total supply of water of 246.59mm was used for CS against 595.45mm for the OS on amaranth, and 270 mm against 675mm on *Moringa*. The frequency of irrigation was reduced from twice a day (OS) to once every 3 days (CS) for amaranth. For *Moringa* it was reduced from once a day (OS) to once every 10 days (CS). Our results show evidence that the CS is an efficient, water economical, autonomous and automatic system which can be promoted to enhance the production of neglected and underutilized vegetables.

Keywords: capillary irrigation, ordinary irrigation, *Amaranthus cruensus* L., *Moringa oleifera* L.

Incidence and severity of *Curvularia* leaf spot on *Digitaria iburua* (fonio) in Riyom, Plateau State, Nigeria.

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Sixteen accessions of *Digitaria iburua* (fonio) collected around Plateau state were planted for disease evaluation in Riyom during the 2011 and 2012 wet season. Diseased plants were identified and samples taken to the laboratory for isolation. Diseased leaves showed dark brown lesions with grey centres. Leaves that showed signs of symptoms were grown on Potato Dextrose Agar with streptomycin and incubated for seven days. Cultures were observed under the microscope and a *Curvularia* sp. was identified. For disease incidence, there were significant differences ($P=0.05$) among the accessions. However, for disease severity there were no significant differences ($P=0.05$) among the accessions. There were no significant differences ($P=0.05$) among the accessions in terms of yield.

Keywords: accessions, fonio, *Digitaria iburua*, *Curvularia*, incidence, severity, Potato Dextrose Agar (PDA)

Targeted influence on rhizospheric conditions for enhancing secondary metabolism in some tropical crops.

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There is growing evidence suggesting that some secondary plant metabolites can confer health benefits to humans. For example, carotenoids or glucosinolates, in vegetables can reduce the risk of some human chronic diseases such as different types of cancer and cardiovascular diseases. The biosynthesis of these metabolites is known to be regulated both ontogenetically and by ecophysiological factors. In this study, different approaches were taken to test and develop suitable horticultural management techniques to improve secondary plant metabolites and health value of some tropical crops. The effect of arbuscular mycorrhizal fungal inoculation at two different phosphorus supply levels on β -carotene concentrations in sweet potato (*Ipomoea batatas* L.) tubers was investigated. In another study, the concentrations of 2-propenyl and 3-indolylmethyl glucosinolates in two lines of *Brassica carinata* (Ethiopian mustard) were assessed during the vegetative life cycle under optimal or drought-inducing water supply conditions. Furthermore, we analysed whether drought stress or additional sulphur supply influenced the glucosinolate content of *Moringa oleifera* leaves in different ecotypes. The glucosinolates of this tree especially - originally native to the sub-Himalayan region - are suspected to cause health promoting effects and are widely used in traditional medicine in Asia and Africa. Mycorrhizal inoculation significantly increased β -carotene concentration in sweet potato tubers at a low P supply level and there was an indication of a direct AM-stimulated carotenoid metabolism rather than by elevated nutrition in AM plants. Similarly, drought-inducing water supply led to a distinct increase of glucosinolates in *B. carinata*, with an indication of a *B. carinata* line-specific drought response. It seems that under drought conditions, there is a shift from primary to secondary metabolism, thereby promoting glucosinolate synthesis. However, in the drought-resistant *M. oleifera* tree, drought and sulphur fertilization-mediated effects on glucosinolates depended on the ecotype, and significant changes were not determined for all ecotypes analysed.

Keywords: carotenoids, glucosinolates, mycorrhiza, Ethiopian mustard, *Moringa*

Local varieties of tangerine growing for food security in Mwanza district, southern Malawi

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As part of agroforestry and income generating activities, fruit growing has been promoted for livelihood and environmental benefits for sustainable agriculture and rural development in Africa. The Malawi Ministry of Agriculture and Food Security (MoAF) and ICRAF have implemented the Agroforestry Food Security Project since 2007. In Malawi, many farmers are engaged in rain-fed agriculture, and maize is the main staple food crop covering 80% of the cultivated area in Malawi. However, the country has experienced recurrent food shortages in 2002, 2005, and 2013 in the southern area. This case study is based on the Mwanza district located in southern Malawi. Mwanza has been considered the largest citrus fruit producing area in Malawi with an elevation of less than 1,200 m and an annual rainfall of 500-700mm (2007 to 2013 seasons). In this district, there are local tangerine trees of unknown varieties. These trees were present before the introduction of improved varieties by MoAF. Local NGOs and missionaries have played important roles in local tangerine growing to contribute to achieving food security especially by providing more income to finance maize production, and increasing nutrition and income at the household level in Mwanza. Currently, those fruits are the most important cash crop for commercial production and this facilitates the purchase of maize grain. Farmers prefer to grow local varieties of tangerine rather than improved varieties. Under these circumstances, basic socio-economic data, the fruit growing situation, maize availability, amount of maize harvested, the onset of food shortages and the cost of inputs for maize growing data were evaluated and recorded to identify the relationship between food security and tangerine growing. Through semi-structured and episodic interviews with 40 local tangerine growers and 40 non-growers, the role of tangerine growing was ascertained. Results of interviews with Mwanza farmers indicated that the income from local tangerine fruit facilitates purchasing not only maize grain as a daily food but also inputs for maize growing, hybrid seeds and chemical fertilizer for their food security.

Keywords: farmers, agroforestry, maize production, local NGOs

Time aspects of food security: the case of remote and peri-urban farming systems in Imo State Nigeria

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Food insecurity is often associated with specific periods in the farm family food production cycle. However, the shortfall at a specific period is often not known. This study focused on isolating the quantity of food supplied to the household, the quantity of food required, and the periods during which shortfalls exist. It also identified the varieties of crops produced and their utilization. The farming and rural systems approach was used and a total of 120 households was selected using a multi-stage random sampling technique. The data were collected with the aid of questionnaires. A hierarchical clustering technique was used to classify the households into Remote and Peri-Urban Farming Systems. The data were analysed using descriptive tools and by computing the food requirement index. The results showed that farm families in the remote farming systems experienced food shortfalls for a period of eight months in a year and could not meet their food requirements through either their own or market supply. The households in the Peri-urban farming systems experienced food shortfalls for a period of four months in a year when their own food production and market supply are unable to meet the family food requirement. They also depend more on the market for food supply both during and after the farming season. The crops grown were the traditional ones known to the area and were often sold and repurchased as the need arose. The understanding and definition of food security defined the crops produced or meals prepared. The need for food preparation and preservation techniques as well as periodic food supply interventions using neglected species is pertinent, particularly in the remote farming systems.

Keywords: time, food supply, food requirement, food utilization, farming systems

Harnessing the potential of breadfruit for African food security: the need for research and extension

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Breadfruit production occurs in the rainforest agro-ecological zones of Nigeria. Two varieties are prominent in the areas. The crop has the potential for alleviating hunger through its cheapness and availability during the season, to provide employment along the value chain, and to support the health of the rural majority. However, this tree has been neglected and its potential is underutilized in Africa. The trees are tall and fruit could not be kept for a long period of time. This study attempts to establish the research and extension need for harnessing the potential of breadfruit in Nigeria. Specifically, it examined the research preference of farmers for breadfruit production, investigated their extension needs, their knowledge of utilization of breadfruit and the market potential of breadfruit in these areas. Focus group discussions were held with farmers in ten villages in the Ife and Ondo environments where the fruits are produced. The findings show that the majority of the farmers inherited breadfruit trees and cultivated on a small scale. The research preferences include: breaking the seasonality, increasing the shelf-life, improved propagation methods and improved varieties with short stem and more fruits. The extension needs include: making breadfruit a priority crop, provision of timely information, fostering partnership between government, NGOs, farmers and other stakeholders for an enhanced market value. The paper concluded that breadfruit could alleviate hunger, provide employment and add to the foreign earnings of Nigeria, if its potential is harnessed.

Keywords: breadfruit, research preference, extension needs, knowledge, utilization

Planting method and seed density effect on vegetable yield and nutrient composition of *Solanum macrocarpon* and *Solanum nigrum*

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Indigenous underutilized vegetables of southwest Nigeria, which have been traditionally used for food security in the past, are gradually being eroded. Increased cultivation and utilization of the vegetables could significantly contribute to food security and poverty alleviation. This study investigated the effects of planting methods and seed density on yield and nutrient contents of *Solanum macrocarpon* and *Solanum nigrum*. The study was carried out at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria between December, 2012 and May, 2013. Soil organic carbon, total N, pH, exchangeable cations and available P were determined. The experiment was a 2 x 2 x 3 factorial design arranged into a randomized complete block, consisting of two planting methods: drill and broadcast, two seed density, four and eight seed spoons and replicated three times. The results showed that *S. nigrum* was ready for harvest at six weeks while *S. macrocarpon* was harvested at eight weeks after planting. Plots with drill and four spoons of seeds produced a significant ($P < 0.05$) increased average of *S. macrocarpon* edible shoots of 2.75 kg m² with highest Ca, K Fe and Zn contents, while the value obtained for *S. nigrum* with the same treatment was 2.95 kg m² and a significant ($P > 0.05$) highest value for only Zn content, compared with planting by broadcast and 8 spoons of seeds. The values observed for other nutrients for *S. nigrum* were identical irrespective of the treatments. It was concluded that planting by drill made weeding, fertilizer application and irrigation more effective rather than by broadcast, and four spoon seeds produced deeper green and broader leaves than eight spoons, and hence recommended for these vegetables.

Keywords: *Solanum macrocarpon*, *Solanum nigrum*, planting method, seed density and nutrient contents

Yield of an acha (*Digitaria iburua* Kippis Stapf or black fonio) accession under the dibbling method of planting at different seed rates.

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Field trials were conducted during the 2011 and 2012 rainy seasons to determine the yield of acha (*Digitaria iburua* Kippis Stapf) or black fonio under the dibbling method of planting at different seed rates in Riyom, Plateau State, Nigeria and the broadcast method of planting (farmers practice) was used as control. The experimental design was a randomized complete block design with three replications. The plot size was 3.0m x 4.0m (12m²) and alleyways of 0.5m and 1.0m between plots and replications respectively. The parameters measured were number of tillers, number of days to 50% panicle emergence, panicle length (cm), number of spikes, spike length (cm), plant height (cm) and grain yield (kg ha⁻¹). The results showed that all the parameters measured were significantly higher under the dibbling method of planting compared to the broadcast (control) in both the 2011 and 2012 seasons and when averaged over the two seasons. Grain yields (kg ha⁻¹) at different seed rates in the dibbling method were significantly higher compared to that of the control. Among the seed rates, the highest grain yield was obtained with 20kg ha⁻¹ in both years of investigation and when averaged over the years. In 2011, plant heights decreased with increase in seed rate with the shortest plants being recorded in the control. In 2012, the control had significantly lower number of tillers and length of spikes than those in the dibbling method. In the combined analysis, the control had significantly less number of tillers, number of spikes, shorter panicle lengths, spike lengths and plant heights than those under the dibbling method at all seed rates.

Quinoa – Prospects as an alternative crop for salt-affected areas

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Pilot studies in the United Arab Emirates (UAE) have demonstrated that quinoa holds promise as an alternative food and feed crop when growing traditional crops becomes uneconomical due to increased groundwater salinity used for irrigation. In on-farm trials conducted under highly saline conditions (EC_w 14 dS/m) in the Western region of Abu Dhabi in collaboration with the Abu Dhabi Farmer's Service Center (ADFSC), the mean seed yield obtained of three quinoa cultivars was 7.5 tons/ha, which was on a par with the highest yields reported from the non-saline traditional quinoa growing areas. The green biomass yield was also high - the mean of the three cultivars being 43 tons/ha - indicating the potential of quinoa as an alternative forage crop for salt-affected areas. The results suggest that quinoa can be used to rehabilitate farms in saline and brackish areas which have been abandoned for cultivation of the traditionally grown crops.

1.2 Conservation

Domestication of a valuable underutilized species in Africa for biodiversity conservation and improvement livelihoods: the case of *Sclerocarya birrea* in Tanzania

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Sclerocarya birrea, commonly known as marula, is an underutilized but potentially valuable tree species for livelihood improvement and conservation of biodiversity in sub-Saharan Africa. This is one of the regions of the world under immense pressure to develop practical solutions for environmental conservation, poverty and food insecurity. Domestication of marula by smallholder farmers has the potential to improve biodiversity, nutrition and household income. This study was done to assess and compare local knowledge, population status, phenology and propagation of marula. Social survey instruments, inventory, GPS mapping, phenological assessments and propagation trials were carried out over a period of three years. Results indicated that lack of processing skills and access to markets are potential barriers requiring immediate attention for marula domestication and commercialization to be taken up. Marula populations were stable and fruiting was affected by rainfall fluctuation and land-use activities. A modified grafting technique which is cost-effective and easily adopted by farmers was developed with 99% success and fruiting after one year which is 8-12 years less than usual. The study recommends farmers to use the grafting technique to plant their own trees in farms through agroforestry. Within a short period they may harvest fruits and develop products such as cooking oil, cosmetics and beverages which can be locally traded while developing a foundation for a large scale commercialization. This study concludes that if *Sclerocarya birrea* is domesticated in Tanzania it can contribute to food security, income generation and environmental conservation. Poor people often refuse to adopt innovations which take many years to return benefits. This study provides a significant solution to the problem through the grafting technique developed. The government, NGOs and researchers have a key role to play in helping farmers to improve the management and utilization of marula.

Enhancing community-based home gardens via improved indigenous knowledge and adaptation to new technologies: a case for the optimal utilization of NUS in Nigeria

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Home gardens play an important role in securing food and income as well as having important cultural significance for the rural poor. For centuries, small farmers and indigenous communities have used very specific knowledge for the cultivation, utilization, marketing and conservation of their indigenous “underutilized” crops. Maximizing the potentials of underutilized crops in rural communities via home gardens can be sustained when approaches that combine indigenous knowledge with science and technology are in place. Using the community, women farmers of Umuanunu-Obinze, Owerri West L.G.A, Imo State, Nigeria, as a case study, this paper highlights various technological approaches which were adapted to improve the community indigenous knowledge for the optimal utilization of their NUS. The project not only provided the essentials for improving NUS home gardens in Umuanunu-Obinze but also counteracted progressive genetic erosion of these crops. It was able to promote and improve their commodity chains and hence an increased marketing potential within local markets around the community. Conclusively, there was a better use of the species in relation to the farmers’ life situation i.e. in their nutrition, health, income as well as strengthening of their cultural identity.

Keywords: commodity chains, home gardens, NUS, technological approaches

Evaluation of *in situ*/on-farm conservation of genetic resources of the fluted pumpkin (*Telfairia occidentalis* Hook. F)

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In situ/on-farm for conservation seems to be the best option for a recalcitrant and neglected crop like the fluted pumpkin. *In situ*/on-farm conservation of biodiversity carried out by farmers year in, year out has resulted in an array of genetic diversity that helps to diversify incomes and livelihoods of the people who engage in production of neglected and underutilized crops. An attempt was made in this study to identify regions with high genetic diversity of the crop. Different collections of fluted pumpkin fruits were collected from ten different states in Southern Nigeria representing three agro-ecological zones (South West, South-South, and South East) for three years. The genotypes were evaluated for five growth parameters and three leaf yield parameters at two locations. Genotypes from the different states and regions were found to be different from one another. Irrespective of year and location, genotypes from the South East had the highest level of genetic diversity and performed best in leaf yield followed by South-South, while most of the genotypes from the South West are characterized by smaller leaves and low leaf yield. The implication of the findings with respect to the prospects for conservation, breeding and commercial seed production are discussed

Keywords: conservation, diversity, leaf yield

1.3 Global and climate change

Growth responses of selected bottle gourd landraces to water stress under controlled environment conditions

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Bottle gourd (*Lagenaria siceraria* (Molina) Standl.) is a popular food crop in rural South Africa where it is grown mostly for its leaves and fruit. Bottle gourd leaves possess huge untapped potential for food and feed industries. There is limited information on the effect of water stress on growth, biomass and fruit yield of bottle gourd. The objective of the study was to determine the response of bottle gourd landrace selections to water stress. Four bottle gourd landrace selections (Zim 1, E4, Cal, Round) were grown under two water regimes (30% and 100% crop water requirement (ET_c)) in a semi-controlled growth tunnel (~33/18°C day/night; 60 - 80% RH) at the University of KwaZulu-Natal, South Africa. An experiment to determine a leafy vegetative crop was laid out as a randomized complete block design with three replications. Plant height, leaf number, branch number, chlorophyll content index, stomatal conductance and male and female flowers were monitored bi-weekly until harvest. At harvest, total leaf area, fresh and dry mass of leaves, stems and roots were determined. At 18 weeks after transplanting, water stress had a negative and significant effect ($P \leq 0.05$) on plant height, branch number, stomatal conductance and stem and total fresh weight and a highly significant effect ($P \leq 0.001$) on leaf number and area. Although, for all traits measured there was no significant interaction between landrace selections and water treatment, E4 was prolific across water regimes and had high branch number (3.5), leaf number (38) and total leaf area (700 cm²) suggesting that it was most suitable for leaf harvesting. On the other hand, Zim 1 had better stomatal regulation (118 mmol m⁻²s⁻¹), more branches (3.83), fewer leaves (24) and higher biomass (56g) compared to the other selections, suggesting that it had drought tolerance potential.

Keywords: bottle gourd, water stress

1.4 Utilization, processing and post-harvest

Production and sensory evaluation of African star apple (*Chrysophyllum albidum*) fruit juice

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African star apple is an underutilized seasonal wild tropical fruit with good flavour, source of vitamins, minerals, calcium and fibre, usually eaten as a snack by breaking and leaking the pulp. Aside from having an average shelf-life of five days, technical challenges such as poor harvesting, handling, storage and processing techniques, result in more than 30 per cent of post-harvest losses of the fruits in Nigeria. This work was aimed at evaluating the overall acceptability of fruit juice formulated from the African Star Apple for value addition as well as to reduce post-harvest losses, increase consumption convenience and boost its economic value. The juice produced was pasteurized at 80° C for 3 minutes, preserved with sodium benzoate [350mg/litre (GRAS)] and the overall acceptability was evaluated using the hedonic scale by a ten-man untrained panel. Samples were coded as: 411- fresh unpasteurised juice; 412- unpasteurised + preservative; 413- pasteurised without preservative and 414- pasteurised plus preservative. According to the descriptive sensory analysis, 411- resulted in 100% agreement in the taste experience; aroma and colour was the same as the fruit. In addition there were no significant ($P>0.05$) differences in the hedonic rank for the juice samples. Although the juice at refrigeration temperatures kept longer than the fruit, it is however recommended that products be used which can keep for a long time at room temperature such as dried pulp flakes which can serve as instant dried pulp to be reconstituted as juice, and so being stable can be better products to boost economic value.

Keywords: underutilized fruit, value addition, fruit juice, potential products

Characterization and screening of indigenous microflora of a traditional fermented African yam bean (*Sphenostylis sternocarpa* Harms) seeds product.

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The objectives of the study were to isolate and characterize the micro-organisms associated with fermentation of African yam bean seeds, to determine the level of involvement of each of the isolates in fermentation of the seeds and to produce a condiment. African yam bean seeds were fermented naturally at 30°C ±2°C for 72 hours, 96 hours and 120 hours. Micro-organisms were isolated and characterized from raw and fermented seeds. The bacteria isolated during the process were *Lactobacillus jensenii*, *Bacillus coagulans*, *Aerococcus viridans* and *Pediococcus cereviseae*. While the yeasts isolated were *Saccharomyces cereviseae* and *Candida mycoderma*, *Aspergillus niger* was the only mould isolated from the raw seeds which disappeared after dehulling. The microbial load increased with the period of fermentation at 72 hours and there was a decrease in the microbial load at 96 and 120 hours of fermentation. At 0 hour, the bacterial count was 6.0x10² cfu/g. At 24, 48, and 72 hours the bacterial counts increased to 7.0x10³, 7.8x10³ and 8.5x10³cfu/g respectively. The highest bacterial load was observed at 72 hours of fermentation. The bacterial load decreased to 4.3x10³ and 2.1x10³ cfu/g at 96 and 120 hours of fermentation. The yeast count of the samples ranged from 2.0x10²cfu/g to 6x10³, 6.7x10³ and 6.8x10³cfu/g at 2, 24, 48 and 72 hours and reduced to 3x10³ and 3x10² at 96 and 120 hours. To conclude, African yam bean seeds can be fermented to produce a condiment, and different micro-organisms responsible for fermentation at different time intervals were documented in the work.

Keywords: African yam bean, microflora, traditional fermentation

Determination of the health status, the nutritional and food security situation of young children and their carers in the Busia District of Western Kenya

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Kenya has a population of approximately 39 million, of whom 60% are under 35 and 52% are women. According to the 2008-09 Kenya Demographic and Health Survey, 35% of children under five are stunted, 16% underweight and 7% wasted. Children living in rural areas and children from poorer households in Kenya are more likely to be malnourished. This study provides an overview of the nutrition, health status and food security of the study population within the pilot project. Structured questionnaires were administered to 200 randomly sampled households. Data were collected on socio-demographic characteristics, nutritional status and food security. An anthropometric questionnaire was used to gather these data. Nutritional status was classified using the WHO age- and gender-specific criteria. Food Security was assessed using Food Consumption Scores, Household Dietary Diversity Score (HDDS), Individual Dietary Diversity Score (IDDS) and Coping Strategy Index. The majority of the household heads were male (78%), with most aged 50 years and above (47.6%). Half of the household heads were unemployed, with 14.6% lacking any formal education and 57.3% having only primary level education. Prior to the survey, 56.4% of children had been sick in the previous two weeks. Although morbidity was higher among male children (59.4%) than females (57.1%), the difference was not significant ($P=0.861$). The main sources of macro- and micro-nutrients were: maize, sweet potatoes, beans, cowpeas and jackfruits. Less than half of the households had three meals per day, while 47.6% had only two meals a day. While only 6% of the adults (>18 years) took three meals per day, 40.5% of children aged 5-18 years had three meals; 27% of children below the age of five had three meals, and only 5.5% had more than three meals a day. At 48.0%, stunting (chronic malnutrition) levels were way above the national figure of 35.3% and 34.2% for the Western province. Stunting is a reflection of failure to receive adequate nutrition over a long period of time and is also affected by recurrent and chronic illness. The food security situation in the area is moderate. There is a need for interventions to improve the nutritional status of the malnourished population. There is a need to promote utilization of locally available indigenous foods.

***Prosopis africana*, a species with multiple utility in Benin**

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Indigenous knowledge and the power of the people are cultural and therefore varies from one ethnic group to another. An ethnobotanical study was conducted with major socio-linguistic groups in Benin: Fon, Adja, Yoruba, Bariba, Fulani, Ditamari Yao-Lokpa and Dendi. Individual interviews and/or in groups were made on the basis of open, direct and indirect questions. This helped to identify the different uses of *Prosopis africana*, to characterize and determine the extent of vulnerabilities and threats to this species and is the only African species among the 45 species that make up the genus *Prosopis*. Scientific work carried out in Benin on *Prosopis africana* do not exist apart from those by Ahoton et al. (2009) on the effect of pre-treatment of seeds of *Prosopis africana*. However significant work has been performed on *P. africana* including its uses in Nigeria Agboola (2004) Annongu (2004), Aremu (2006) Barminas (1998) Gérardin (2004), Yusuf (2008) in Niger: Boureina (2001) in Burkina: Dah (2009) in the Sahel: von Maydell (1983) and in dry areas in West Africa: Arbonnier (2002). Our survey was conducted from mid-July to mid-August and September-October 2012, and we identified 102 uses of *P. africana* which are medicinal, for food, crafts, magic, etc.. These uses are particularly noted for the Adja and Bariba groups with respectively 46 and 42 applications. The Lokpa and Ditamari come in last place with 25 uses. The research showed that the leaves are the most useful and the seeds are used for human consumption. Also from this research, it appears that the flowers are less utilized. *P. africana* is a threatened species and very few traditional conservation methods have been developed.

Keywords: *Prosopis africana*, ethnobotany, medicinal plants, vulnerable plants, Benin

Utilization and socio-economic importance of *Moringa oleifera* Lam. in the savannah zones of central Africa: the case of the city of Maroua in northern Cameroon

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This study investigated the uses of *Moringa oleifera* by the people of northern Cameroon in particular the city of Maroua. The study highlights the different parts of *M. oleifera* used and the population's overview of the availability of different parts of this plant in the dry savannah zone. To achieve the objectives, the following questions were put to the population: i) what is the level of use and/or consumption of *M. oleifera* in the city of Maroua? ii) the supply level of *M. oleifera* demand for food? The method used for this purpose was essentially by surveys involving 60 households in six districts and 60 sellers, retailers of leafy vegetables in six daily markets of the city of Maroua and were supplemented with field observations. It appears that ninety-five percent (95%) of respondents are aware of *M. oleifera* and 93.4% of them use the leaves. *M. oleifera* leaves are mainly used as food by the people of the city of Maroua in the form of "sauce". Sixty (60.64%) percent use the roots, and 2% the seeds. These two parts are used in traditional medicine. The gardens are also the best places to supply households. Forty-three percent (43.33%) of sellers-retailers of *M. oleifera* are supplied from peri-urban areas. Sellers-retailers (51.66%) believe that the sale of *M. oleifera* leaves is profitable and even 26.66% of them say it is twice as profitable as other leafy vegetables. The flow of *M. oleifera* leaves reaches its optimum market during the period from July to September, which corresponds to the rainy season. Awareness about cultivation techniques, management practices and uses of this tree is necessary for its value, availability and sustainability. This scientific work was aimed to provide to the rural populations in particular general technical references on the production and uses of different parts of *M. oleifera*. Policymakers should take steps to make *M. oleifera* available to all people through the creation of farms which will provide leaves, seeds and roots of this species throughout the year.

Keywords: *Moringa oleifera*, uses, availability, northern Cameroon, Maroua

Effect of processing on nutrient and anti-nutrient components in *Parkia biglobosa*

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Parkia biglobosa commonly called African Locust bean is a perennial, deciduous, multi-purpose tree that belongs to the family Fabaceae. There have been wide reports on the uses of various parts of the plant in home remedies for the treatment of diabetes, malaria, female sterility, leprosy, eye sores, toothache, snake bites, fever, hypertension and for treatment of wounds and ulcers. The potential of the plant in human and animal nutrition has, however, not been fully explored. This study compared the effects of two processing methods used in Nigeria, namely boiling and fermentation, on nutrient composition of seeds of this crop. Proximate composition, amino acid level and anti-nutrient factors (polyphenols, phytic acid and oxalate) were determined at three stages: raw, boiled and fermented. The highest anti-nutrient factor present in the raw state was oxalate, while phytic acid was the lowest. Crude fibre, protein and carbohydrate contents were significantly higher ($P < 0.05$) in boiled than in fermented samples. However, fermentation was more effective in reducing the anti-nutrient factors in the seeds of this plant. The significance of these findings in the nutrition of humans and livestock is discussed.

Keywords : *Parkia biglobosa*, fermentation, boiling, nutrient composition

Households' purchasing decision for underutilized leafy vegetables in the Limpopo Province: a double-hurdle model approach

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The over-dependence on a handful of staple crops results in major challenges, and so diversification to alternative crops will be important as part of the goal of achieving security of food production. This study examines the factors affecting household purchasing decisions for underutilized leafy vegetables (ULVs) in the Limpopo Province of South Africa using a double-hurdle model that accounts for both market participation (whether the household bought or not) and intensity of consumption decisions. Participation and consumption were analysed using cross-sectional data collected from 300 households in 2012. The results indicated that factors that affect participation may not necessarily affect consumption of ULVs. Such factors include gender, level of income, and awareness of ULVs. However, factors such as household size and distance to the market affect consumption but not participation, mainly due to consumption from own subsistence production. In addition, factors such as street vendor markets and households' perception that ULVs are safe to consume affect both participation and consumption. As other exotic leafy vegetables such as cabbage and Swiss chard (spinach in South Africa) are available all year round, it would be beneficial for consumers to have access to ULVs. To this effect, agricultural policy measures need to be taken to enable local producers to supply ULVs throughout the year.

Keywords: underutilized leafy vegetables, purchasing decision, Limpopo Province, double-hurdle model

Evaluation of youth and farmer participation in cocoyam rapid multiplication technology for increased cocoyam production in Imo State Nigeria.

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Cocoyam is one of the major underutilized crops in Nigeria. It does not appear to have been one of such crops given attention in science and technology in Nigeria, so the crop has trailed behind other staple foods as a candidate for orderly scientific research to compare with cassava yam potato and sweet potato. A study was carried out in Mbaise and Ehime mbano in Imo state Nigeria to determine the level of interest and participation of youths and farmers in cocoyam rapid multiplication technology. One hundred and six respondents were purposively selected and interviewed by means of structured questionnaires. They were selected because the technology was demonstrated for them for increased production and utilization of cocoyam in the area. The results of the study showed high interest and participation in cocoyam technology (96.22% and 92.45% respectively) among the respondents in all the cocoyam rapid multiplication technology activities demonstrated, ranging from planting to harvesting stages of production. There was a high level of participation. It was only disease control measures and seed selection that had low levels of participation. The result also showed that only about 47.2% of respondents produced up to 2000kg of cocoyam per annum while 41.50% did not plant cocoyam at all. Results of correlation analysis of the socio-economic characteristics of the respondents with the level of participation shows that age was significant in processing and marketing of cocoyam at the 1% and 5% level of significance. This shows that the level of participation of the respondents was dependent on their age; the higher the age of the people the higher their participation in cocoyam production activities and it shows that cocoyam was mainly grown by elderly people in the study area. It was recommended that cocoyam production should be encouraged among young people and more production technologies should be transferred to farmers through demonstration methods of teaching because their interest in cocoyam technology depends on their participation. This will help to increase cocoyam production and utilization in Nigeria.

Keywords: cocoyam, technology interest participation

Extrusion processing of neglected and underutilized species: prospects , challenges and opportunities for food security in Africa

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Neglected and underutilized species have great potential towards food security, sustainable agriculture and improving the socio-economic situation of the poor rural sector. One of the means to enhance the contribution of neglected and underutilized species to food security and to incomes of the rural poor is by the expansion of processing technology. Also, there is the need for proper processing to other forms to improve the face value of products after harvest. Food extrusion is a process for producing a range of products with different shapes, textures, colours, and flavours from basic ingredients, thereby increasing the variety of food in the diet and also materials for the industry. In this paper, we review the principles of extrusion cooking, provide an overview of the current and future applications of food extrusion relevant to the processing of neglected and underutilized species, and identify the challenges and implications for the successful implementation of food extrusion technology for processing of neglected and underutilized species particularly in sub-Saharan Africa and offer suggestions on how to overcome the identified challenges.

Keywords: food extrusion, herbs, spices, quality, value addition

Effect of post-harvest losses of traditional vegetables on market participation by smallholders in Tanzania

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Smallholder production of traditional leafy vegetables is an important activity even though these crops are perishable and prone to high post-harvest losses. We examined post-harvest losses in traditional leafy vegetables compared with cash crops to estimate the impact of post-harvest losses on market participation and marketed surplus. The study analyzed 240 farm households from the Arusha, Tanga and Morogoro regions in Tanzania that cultivated amaranth (*Amaranthus* spp.) and/or produced tomato as a cash crop. Systematic random sampling was used to draw samples for the survey and an econometric analysis was conducted. More than 81% of respondents who grew tomato reported spoilage between harvesting and selling, whereas only 39% of amaranth growers experienced spoilage in their crops. Loss due to mechanical damage was 2.35% for amaranth and 17.05% for tomato. Economic losses were reported to be 131 TSh for amaranth and 2057 TSh for tomatoes per transaction. Although post-harvest losses were higher for tomato, field observations showed that market participation in terms of number of tomato producers was high compared with amaranth growers. Tomato cultivation is considered to be capital-intensive compared to production of traditional leafy vegetables. To improve the livelihoods of smallholders, it is important to increase their access to better technologies and infrastructure for amaranth production and value addition, which may result in lower post-harvest losses and increased market participation.

Keywords: post-harvest losses, traditional African leafy vegetables, market participation

1.5 NUS for nutrition and health

Variation in nutrient composition in 20 accessions of *Tetrapleura tetraptera* (Schum. and Thonn.) from Cross River State, Nigeria and its implication in breeding programmes

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Tetrapleura tetraptera (Schum. and Thonn.) is highly valued for its nutritional and medicinal attributes. However, the plant grows wild in the forests and is getting gradually wiped out with no substantial conservation or breeding efforts made. In this study, dry pods of twenty accessions of *T. tetraptera*, collected from six local government areas in Cross River State, Nigeria, were evaluated for their phytochemical, proximate, vitamin, and mineral compositions. Genetic variations were determined based on analysis of variance methods. High estimates of broad sense heritability with relatively high genetic advance were obtained for saponin, riboflavin and niacin contents, indicating that these attributes were under the control of additive gene effects. Therefore, the plant can be improved with respect to these attributes through direct selection. However, relatively high estimates of broad sense heritability with low genetic advance were obtained for other attributes, indicating the presence of non-additive gene action. Direct selection for such attributes may not be effective. Dendrograms resulting from analysis of the matrix of similarities grouped the accessions into four clusters. Members of cluster 1 had low tannin content, moderate fat and calcium contents, while sterol, thiamine, potassium and sodium contents were high. Cluster 2 had low alkaloid and thiamine contents, high ash, saponin and vitamin A contents. Cluster 3 members were rich in crude fibre, carbohydrate and tannins, but low in total fat and calcium. Cluster 4 was characterized by high fat, alkaloid and niacin with low zinc, phosphorus, magnesium, vitamin A, hydrogen cyanide, saponin, and carbohydrate. The unique features observed among accessions in each cluster could be exploited for varietal improvement. Accessions AKA3 (from cluster 1), IKM1 (from cluster 3), AKP3 (from cluster 2), AKP5 (from cluster 3) and BOK1 (from cluster 4) were identified as superior accessions based on multiple trait performance.

***Cordia africana* fruit nutritional composition across different agroecology and land use in northern Ethiopia**

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In the world we find a lot of lesser known but locally used plants and fruits. These indigenous fruits and plants make substantial contributions to food security and nutrition. *Cordia africana* (Lam.) is a small fruit eaten in Ethiopia and Africa. The fruit was tested for its moisture content, total soluble solids (30% fruit in water), pH (30% fruit in water), total acidity (30% fruit in water), ash, crude protein, Ca, Cu, Fe, K, Mg, Mn, Na, P, Zn, vitamin C and A, size, weight and colour across four different agro-ecologies and three land uses. The fruit is a very good source of calcium and vitamin C. In addition, consuming 600 grams of this fruit will meet at least half the daily the nutritional requirements of protein, Cu, Fe, K, Mg, Mn, P and vitamin A. FAO notes a chronic iodine, vitamin A and iron shortage in Ethiopia. The *C. africana* fruit can be used as a partial source of vitamin A and iron. The tested nutritional aspects of the fruit were found to vary more with agro-ecology than with land use. In conclusion, it can be noted that *C. africana* is a nutritious fruit, which should be promoted in planting, processing, marketing and consumption throughout Africa.

The role of *Gongronema latifolium* in attenuation of chloroquine induced nephrotoxicity and hepatotoxicity

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The objective of this study was to investigate the attenuated effect of *Gongronema latifolium* against chloroquine-induced nephrotoxicity and hepatotoxicity in wistar rats. Twenty wistar rats were divided into four groups of five rats per group. Animals in group one served as control while animals in groups 2, 3 and 4 received a single oral administration of chloroquine (970mg/kg body weight). However, experimental groups 3 and 4 were additionally treated with 250mg/kg and 500mg/kg body weight of leaf extract of *Gongronema latifolium* respectively. The treatment lasted for 14 days. The results obtained showed that serum urea and creatinine significantly increased in group 2 compared to group 1, but significantly reduced in group 3 and 4 when compared with group 2 ($P < 0.05$). On the other hand, serum bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP) levels were significantly increased in group 2, when compared with the control. However, the level of serum bilirubin, AST, ALT, and ALP levels dropped marginally in groups 3 and 4. This observation probably implies that the leaf extract of *Gongronema latifolium* attenuated the nephrotoxicity and hepatotoxicity induced by chloroquine. Hence the use of *Gongronema latifolium* could be helpful to patients with problems of liver and kidney functioning.

Keywords: chloroquine, nephrotoxicity, hepatotoxicity, *Gongronema latifolium*

Wild nutraceutical plants from Nebbi district, Uganda

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An ethnobotanical study was conducted to inventory the wild plant species used as both food and medicine and how they are used in Panyago Sub County, Nebbi district, Uganda. Data were collected using questionnaires; focus group discussions and field observations. Both purposeful sampling methods and simple random sampling methods were used to obtain the required information. Forty four plant species belonging to 28 different plant families were reported to have an overlapping use as both food and medicine. They were used to treat 32 diseases, the most common being stomach ache. The leaves were the most frequently used parts of the plants as food (45.1%), while the roots were the most commonly used parts of the plants as medicine (33.8%). Some of the plant species had the same parts used for both medicine and eaten as food (26.1 %), while other plant species had different parts used as either food or medicine. Infusions were the most commonly used method of preparation, while most medicines were administered orally.

Numerous plant species are used for a dual function of providing medicine and food concurrently. Many families in this area still heavily rely on these plants for both their perceived nutritional values, as food and curative values, despite the fact that the custodians of this knowledge are not consistently transferring it to the younger generations.

Keywords: nutraceutical, food, medicine, wild

Antioxidant health benefits of neglected and underutilized *Ereromastax* species in Nigeria

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A critical step towards improvement of global health care delivery systems lies in the discovery and optimal utilization of the wide range of medicinal plant resources available in nature. Against this backdrop, the antioxidant potentials of two underutilized crops, *Ereromastax speciosa* and *Ereromastax polysperma*, growing under lowland humid tropical conditions of southern Nigeria, were investigated using selected complementary *in vitro* assay systems. Ascorbic acid, gallic acid and Na₂EDTA were used as standard reference compounds and the plants' leaves were extracted using 80% ethanol. Extracts of the two species contained good amounts of antioxidant metabolites (36.44 – 57.56 µg gallic acid equivalents/mg, and 67.83 – 141.58 µg rutin equivalents/mg for total phenol and flavonoid contents respectively). The extracts scavenged 50% of stable DPPH radicals at concentrations of 40.76µg/ml and 89.14µg/ml, and chelated 50% of iron ions (Fe²⁺) at concentrations of 1.14mg/ml and 1.21mg/ml. Results of the reducing power assay and total antioxidant capacity indicated that the extracts were potent in electron donation and thus were capable of reducing Fe³⁺ and Mo (VI) ions to their lower oxidation states. *Ereromastax polysperma* generally showed superiority (P<0.05) to *Ereromastax speciosa* in all the test assays. The results obtained are significant pointers to the potential health benefits of these underutilized plants to humans and animals as antioxidants that could provide natural mitigation of the hazardous effect of free radicals.

Leaves of ground cherry (*Physalis angulata* L.) may be suitable in alleviating micronutrient deficiency

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Physalis angulata (L.) is an annual herbaceous neglected underutilized species used as a vegetable and in herbal medicine for the treatment of infectious diseases in Nigeria. This study evaluated proximate, minerals and amino acids content of *P. angulata* leaves and fruits using standard methods with a view to understanding its nutritional potential. The leaves and fruits had crude protein content of 27.80% and 10.97% respectively. The fruits had the highest sodium content of 689.48mg/100g while, the leaves had the highest content of manganese with 21.60mg/100g. The result of amino acid analysis indicated that the leaves had isoleucine, valine, phenylalanine plus tyrosine contents of 3.04, 4.36 and 6.38g/100g protein respectively, which are within WHO ideal protein standards. These components are however low in fruits except phenylalanine plus tyrosine, and leucine with 5.22 and 5.16g/100g protein respectively. Concentration of phytate was 6.91mg/100g in the leaves and 8.59mg/100g in the fruits. Similarly, oxalate content was 2.74 and 3.21mg/100g in the leaves and fruits respectively. Prediction of minerals bioavailability indicates that the concentration of oxalate and phytate may interfere with bioavailability of calcium, zinc and iron. The concentration of [Phytate]/[Zn] in the leaves was comparatively low (5.32) which is an indication of its potential in a food-based strategy to alleviate zinc malnutrition. The results of this study indicate that leaves of *P. angulata* contain substantial amounts of nutrients suggesting its potential as a source of nutrients that could be useful in alleviating micronutrient deficiency.

Keywords: *Physalis angulata*, micronutrient, amino acids, bioavailability

Neglected and underutilized insect species for nutrition and health

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Insects are the most diverse group of animals on earth with over one million different species. They have interacted with man in diverse ways for several millennia as food, medicine and in other cases as his competitors for resources. Estimates of the number of insect species that are consumed by humans vary, but worldwide at least 1400 species have been recorded as human foods. In modern times, entomophagy has declined in many societies, and has often been shunned as old-fashioned, dirty or unhealthy. All the same, in various cultures throughout the world, insects remain a vital and preferred food and an essential source of protein, fat, minerals and vitamins.

Insects are exceptionally efficient in converting what they eat into tissue that can be consumed by others. Insects are about twice as efficient as chicken and pigs and more than five times as efficient as beef in doing this. Due to their astounding reproduction rates and fecundity, the actual food conversion efficiency of insects may be 20 times that of cattle. Moreover, insects feed on a far wider range of plants than conventional livestock. One hundred grams of dried caterpillars contain 52.9 grams of protein, 15.4 grams of fat, and 16.9 grams of carbohydrates and have an energy value of 430 kcal. As a food source, insects are highly nutritious. Many insect species contain as much or more protein as meat and fish. Some insects, especially in the larval stage, are also rich in fat and most insects contain significant percentages of amino acids and essential vitamins and minerals. Hence there is a need for research on the identification, distribution and nutritional potential of edible insect species as alternative foods which would help to mitigate food insecurity and malnutrition.

Keywords: neglected and underutilized insects species, entomophagy, amino acids, malnutrition.

Proximate composition of ackee apple fruits

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Ackee apple (*Blighia sapida*) is an underutilized woody perennial multi-purpose fruit tree species native to the Guinean forests of West Africa. The fleshy arils of the ripened fruits are edible. Capsules of the fruits are used for soap making and all parts of the tree have medicinal properties. The main objective of the study was to assess the proximate composition of the ripened fleshy arils of ackee apple fruits. The knowledge of these constituents will increase domestication of the plant and would directly influence the nutrient needs of households, provide income generation and agro-ecosystem diversification. Ripened ackee apple fruit samples were collected and analysed for fat, fibre, protein, ash, moisture and carbohydrate using recommended methods of the association of official analytical chemists. All analysed parameters were in triplicate. Mean values of the results in percentages were: crude fat (49.28 ± 0.30), crude fibre (17.29 ± 0.08), crude protein (14.60 ± 0.12), moisture content (9.12 ± 0.19), ash content (5.18 ± 0.21) and carbohydrate (4.53 ± 0.00). From the results, edible ackee apple fruits contain all needed nutrients in relative proportions to aid in the supplementations of nutrient needs of consumers. The edible fruits however contain high percentage of fats and should be consumed in moderation to ensure nutrient balance.

Keyword: ackee apple, arils, nutrient composition, underutilized trees

Management of underutilized medicinal plants in Nigeria using phenological information

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The West African sub-region including Nigeria is blessed with arrays and diversities of medicinal plants with high rural health care services, food security and pharmaceutical potential. However many of them remain neglected, underutilized or, at best, traditionally utilized. Available information indicates increasing habitat loss without corresponding conservation and silvicultural programmes. Efforts at improving their conservation and utilization led to an eco-pharmacological survey in the West African sub-region in three countries (Nigeria, Ghana and Republic of Benin) to assess frequently used medicinal plants. Initial results of the socio-economic study based on utilization patterns regionally were used to produce a list of ten topmost frequently mentioned medicinal plants and was modified for the eco-pharmacological study in Nigeria. The list was superimposed on a vegetation map of Nigeria for study site selection range-wide. Site selections were based on the presence of at least one or more medicinal plants in each location. Their phenological behaviours were monitored consecutively over two seasons (dry and rainy seasons). Findings indicated that the ten medicinal plants belonged to nine taxonomic families and had representation in the three plant habits. Flowering was typical in the dry season (November-February) occasionally extending to early rainy season (March-May) in the species' southern range. Mean flowering duration ranged from 9.45 ± 1.73 to 45.68 ± 4.77 days and fruiting from 15.22 ± 2.15 to 145.87 ± 8.59 days. Phenological charts were used to depict their phenological trends. The present findings offer a useful tool-kit for these medicinal plants' genetic resources management, appropriate conservation and utilization strategies in Nigeria

Keywords: indigenous medicinal plants, eco-pharmacological survey, phenology, conservation

Using sweet potato forage as a vegetable to reduce mineral nutrition deficiency in young children in Kenya

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Micronutrient malnourishment causes learning disability among children, increases morbidity and mortality. Sweet potato forage is underutilized in Kenya as a vegetable and its benefits as a source of dietary minerals are not well documented. The study objectives were to evaluate three forage sweet potato cultivars for their calcium (Ca), magnesium (Mg), iron (Fe) and zinc (Zn) content and their potential to meet Ca, Mg, Fe and Zn requirements of children aged four to six years. Cultivars 99/1, K158 and Marooko, were planted in a randomized complete block design with three replicates. Cuttings were planted in rows 60 cm wide and 30 cm apart and fertilizer was applied according to standard recommendations. The cultivars' above ground vegetable matter was harvested at 120 days, sampled and analysed for Ca, Mg, Fe and Zn. The data were analysed using the general linear model of SAS and means separated using least significant difference procedures. Cultivars 99/1, K158 and Marooko contained 6.10, 7.68 and 8.41; 4.78, 5.15 and 3.20 g/kg dry matter (DM), 388.0, 326.3 and 286.7 and 178.7, 180.7 and 179.7 mg/kg DM Ca, Mg, Fe and Zn respectively. Using WHO/FAO (2005) recommended nutrient intakes (RNI) the children will eat the respective cultivars' vegetable matter weighing 98.4, 78.4 and 71.1; 15.9, 14.8 and 23.8; 32.5, 38.6 and 44.0 and 53.7, 53.2 and 53.4 g DM to meet their RNI of Ca, Mg, Fe and Zn respectively. Marooko, K158 and 99/1 contained the highest Ca, Mg and Fe respectively while K158 contained the highest Zn. According to this study, once the quantity of vegetable attains RNI for Ca, the other micronutrients RNI are met too. The daily vegetable weight per child is relatively little and so these cultivars should be grown and widely fed to children aged four to six years to reduce Ca, Mg, Fe and Zn deficiency in Kenya.

Keywords: micronutrients deficiency, calcium, magnesium, iron, zinc

Levels of phytates and oxalates in recipes formulated from selected underutilized local vegetables from the Lake Victoria Basin, Kenya

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Local vegetables in the Lake Victoria Basin (LVB) that could provide micronutrients to fight hunger contain phytates and oxalates that reduce bioavailability. These can be reduced through appropriate traditional food processing techniques adopted in households. The phytate and oxalate levels in underutilized local vegetables (ULVs) have not been clearly assessed to identify possible suitable processing techniques and dietary combinations that can contribute towards micronutrient bioavailability. The aim of this study was to determine the content of phytates and oxalates in formulated ULV recipes. This was an experimental design with eleven selected ULVs: saget (*Cleome gynandra*), pumpkin leaves (*Curcubita moschata*), cowpea (*Vigna unguiculata*), amaranth (*Amaranthus blitum*), jute mallow (*Corchorus olitorius*), sweet potatoes leaves (*Ipomoea batatas*), managu (*Solanum nigrum*), cassava leaves (*Manihot esculenta*), Mito/slender leaf (*Crotalaria ochroleuca*), nderema (*Basella alba*) and kale (*Brassica carinata*). Eleven single vegetables and five vegetable combinations were boiled and divided into two lots. One lot was fermented for 48 hours and the other was not fermented. The non-fermented lot was subjected to three treatments: cooking by boiling, stewing, addition of cow's milk and lye. Phytate and oxalate content were determined using HPLC. The independent t-test was used to compare the mean content of anti-nutrients between fermented recipes and non-fermented recipes. ANOVA was used to compare the mean content of the anti-nutrients between different methods of cooking. Mean levels of anti-nutrients in different ULVs were significantly different ($P < 0.05$). Fermentation significantly reduced anti-nutrients in some ULVs. Mean levels of phytates in ULVs were generally higher than those of oxalates in the same vegetables. Overall phytate and oxalate levels were lower in fermented vegetables. Cooking methods differentially affected the levels of anti-nutrients. In some ULVs, a decrease of anti-nutrients was observed while in others there was no significant change.

Keywords: phytate and oxalate levels, recipes, fermentation, cooking methods, underutilized local vegetables

Traditional vegetable recipes in Cameroon

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The consumption of traditional vegetables helps to address malnutrition. Traditional vegetables often are rich in pro-vitamin A and vitamin C, several mineral micronutrients, and health-promoting phytochemicals with antioxidant, antibiotic and anticancer and other nutraceutical properties. Nevertheless, the consumption of traditional vegetables is still low in Africa, especially among younger people. Traditional vegetables are often perceived as tasteless and bitter - thus their appearance, flavour and texture must be enhanced to increase consumption. Development and dissemination of recipes incorporating vegetables for tasty and attractive meals is an important but neglected research area. We seek to contribute to balanced diets and alleviate malnutrition by promoting tasty recipes to increase the consumption of nutritious traditional vegetables. Appropriate combinations of foods can make the consumption of traditional vegetables a pleasant experience, and optimize the intake of essential nutrients. Located at the crossroads of West and Central Africa, Cameroon is regarded as the melting pot of Africa; it is often referred to as “Africa in miniature” because of its great diversity in culture, ethnic groups, geographic representation and culinary dishes. We collected recipes for traditional vegetables including amaranth, nightshade, African eggplant, jute mallow, and okra, which are among the most consumed vegetables in Cameroon. Previous studies revealed that most people in Yaoundé consume vegetables for taste and to improve their health. Taste, texture (for okra, the amount of mucilage), and smell after cooking were factors that increased satisfaction during consumption. Twenty-three vegetable recipes collected from Cameroon’s ten regions were documented.

Keywords: traditional vegetables, recipes, nutritional security, micronutrient malnutrition, vegetables

Health and nutritional potential of okra (*Abelmoschus* spp L.) for reducing malnutrition in rural Ghana

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Ten commonly cultivated varieties of Okra (*Abelmoschus* spp. L.) were collected from eight geographic regions of Ghana and were evaluated for their phytochemical constituents. Nine essential mineral elements were determined in fresh fruits of these varieties of okra using Instrumental Neutron Activation Analysis. The objective of the study was to assess total flavonoid, phenolic, antioxidant activity and essential mineral contents in the varieties. Results indicate that, there are statistically significant differences ($P \leq 0.05$) in total flavonoid contents (TFCs), total phenolic contents (TPCs) and total antioxidant contents (TAAs) recorded for both the ethanolic and aqueous extracts and concentrations of essential minerals of the varieties, indicating genetic variability among them. The high variability observed in the amounts of TFCs, TPCs and TAAs in the fresh fruits of okra, makes okra a good source of natural antioxidants. Concentrations of the essential elements were correlated to assess the degree of association existing among these elements and were juxtaposed with their recommended daily intake in the individual varieties of okra. The unearthed compositional values of okra in this study make it a candidate crop for reducing malnutrition among consumers.

Keywords: okra, antioxidants, phenolics, flavonoids, essential minerals.

Ascorbic acid, total phenolic content, flavonoid and antioxidant activity of two cultivars of *Basella alba*

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Antioxidants and secondary metabolites have attracted a great deal of attention for their effect in preventing disease due to oxidative stress, which leads to degeneration of cell membranes and many pathological diseases including cancer. In the current study, two cultivars of *Basella alba*, an underutilized vegetable, were evaluated for their ascorbic acid, total phenolic, flavonoid and total antioxidant activities. Green and red cultivars were analysed by standard methods. Ascorbic acid varied: in green cultivars it was 19.38 mg/100g and in red cultivars it was 25.85 mg/g fr wt. The variation in ascorbic acid content was highly significant ($P < 0.05$). Total phenolic contents were 61.00 and 90.52 mg/g fr wt., with no significant variation ($P < 0.05$). Ferric reducing power for the green cultivar was 5.93mg/g while for the red cultivar it was 10.56mg/g fr wt., significant differences being observed in the ferric reducing power of the two cultivars. DPPH of the green cultivar was 78.85% while for the red cultivar it was 79.81%, no significant difference being observed between the cultivars. Total antioxidant activity for the green cultivar was 60.86 mg/g while for the red cultivar it was 70.38 mg/g fr wt., no significant difference being observe in the total antioxidant activity. Both cultivars were excellent sources of ascorbic acid, total phenolic compound, flavonoid and total antioxidant properties although the red cultivar had higher values. The cultivars have enormous potential to enhance the antioxidant potential of our daily food supply and serve as nutraceuticals.

Keywords: underutilized vegetable, ascorbic acid, antioxidant activity, *Basella alba*

Survey of heavy metals in sea food and farm produce from Akwa Ibom (Nigeria): levels and health implications

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The main objective of this survey was to obtain representative data on levels of heavy metals in sea food and farm produce consumed by the general population in Uyo, Akwa Ibom State, Nigeria a 'crude oil exploration' city. Commonly grown fruits, food crops and sea foods were purchased from Uyo metropolis, while the vegetables were collected from farmlands in Uyo. Dried samples were ground, digested, centrifuged and heavy metals (Pb, Cd, Ni, Co and Cr) were analysed using Atomic Absorption Spectrophotometry. The daily intake and target hazard quotient (THQ) were estimated.

Eight food items comprising cereals (millet and maize), seafoods (periwinkle, crayfish, stock fish, sabina fish and bonga fish) and vegetable (pumpkin leaf) had THQ values for cadmium over 1.0 indicating a potential health risk. All other metals had THQ values below 1.0 indicating that the health risk may be insignificant. The total THQ for the metals ranged from 0.389 to 2.986. Fourteen of the food items had total THQ values greater than 1.0 also indicating some health risks via their consumption. Consumption of both sea foods and some farm produce may likely add to the body burden of heavy metals in Akwa Ibom State, Nigeria.

Nutrient composition of cowpea *Vigna unguiculata* treated with some plant oils to control cowpea weevil *Callosobruchus maculatus* (Fabr.)

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Three varieties of cowpea, IITA striga resistant variety and two local cultivars Dangidan Yunfa (DGY) and Dan Kalabaz (DKB), were sterilized by freezing. Two hundred and fifty grams of each of the cowpea varieties were treated with different amounts of oil extracted from the seeds of *Acacia nilotica*, *Balanites aegyptiaca* and *Senna occidentalis*. These were infested with ten pairs of one day-old adults of *Callosobruchus maculatus* and stored in the Physiology Laboratory of Usmanu Danfodiyo University, Sokoto for 12 weeks. Untreated cowpea was similarly set up as a control. Both the treated and untreated samples were replicated three times. Biochemical analysis showed higher moisture contents in the control than treated cowpea. On ash and dietary fibre contents, oils resulted in the same effect with phostoxin on all the cowpea varieties with no significant difference ($P>0.05$). Also crude protein and total fat contents were significantly higher ($P<0.05$) on oil-treated samples than the control. However, no noticeable differences were observed among the various treatments. Equally there was no difference in the inorganic mineral content of the cowpea varieties.

Keywords: cowpea varieties, plant oils, *Callosobruchus maculatus*, biochemical analysis

Evaluation of chemical composition, phytochemical constituents and antioxidant potentials of lima bean seed coats

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Natural antioxidants are presumed to be safe since they occur in plant foods. It was known that antioxidant phytochemicals in foods have many health benefits including prevention of various diseases associated with oxidative stress such as cancer, cardiovascular disease, neuro-degeneration and diabetes. The Lima bean (*Phaseolus lunatus*) seed coat was evaluated for its chemical composition, phytochemical constituents and *in vitro* antioxidant activity.

Antioxidant activity of seed coat flour was investigated by measuring its DPPH (1,1-diphenyl-2-picryl hydrazyl) and ABTS (2, 2'-azinobis-3-ethyl-benzothiozoline-6-sulphonic acid) radicals scavenging ability as well as its ferric reducing property. The chemical analysis indicates that the coat has moisture (4.46%), protein (15.75%), fat (0.65%), crude fibre (33.56%), ash (2.57%), carbohydrate (47.52%) on a dry weight basis; zinc (5.6mg/100g), calcium (17.56mg/100g), potassium (82mg/100g), sodium (398mg/100g), magnesium (87.1mg/100g), iron (11.61mg/100g) and manganese (0.13mg/100g). Phytochemical screening revealed that flavonoids, alkaloids, saponins, tannins and phenolic compounds are present and may be responsible for the activity. HPLC-DAD analysis revealed the presence of phenolics (gallic acid, caffeic acid, ellagic acid, rutin, quercetin and kaempferol) and tocopherol. The seed coat flour exhibited significant radical scavenging activity against DPPH (IC₅₀ value 0.083±0.003mg/ml) and ABTS (IC₅₀ value 0.45± 0.04mg/ml; Trolox Equivalent Antioxidant Capacity, TEAC value = 0.01) and considerable ferric reducing property (66.70± µg ascorbic acid equivalent/mg seed coat powder). It is concluded that the seed coats have a potential source of antioxidants of natural origin.

Keywords: *Phaseolus lunatus*, seed coat, composition, antioxidants, polyphenols

Potential toxicity in cassava: a barrier to its food security

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Cassava (*Manihot esculenta* Crantz) is a drought-tolerant crop, grown in tropical and subtropical areas as a source of food. In Kenya, cassava is an important staple food and animal feed. The status of cassava as a food-secure crop, however, is threatened by pests, diseases and weeds, and its potential toxicity. Cyanogenic glycosides in cassava produces toxic hydrogen cyanide. The concentration of these cyanogenic glycosides has been reported to vary with the age of the plant, the variety and ecological conditions in which the cassava grows. In this study, we report the variation of concentration of cyanogenic glycosides (in the form of hydrogen cyanide) in cassava collected from five different regions of Kenya where cassava is consumed. Determination of cyanide concentration was carried out by the picrate paper method. There was significant variation ($P < 0.05$) in the concentration of cyanide in cassava from the five different regions. The concentration of cyanide in cassava from Kakamega was highest (80.79 ± 4.55 mg/kg), while cassava from Kisii had the lowest cyanide concentration (43.27 ± 3.75 mg/kg). The cyanide concentration in cassava from Kitui was equally high at 70.46 ± 2.21 mg/kg, while Nairobi and Thika had moderate levels at 66.00 ± 2.12 mg/kg and 54.84 ± 0.65 mg/kg respectively. The concentrations of cyanides in cassava from all the five regions were higher than the levels recommended by the WHO (10 mg of HCN/kg body weight).

Keywords: cassava, cyanogenic glycosides, cyanide, drought tolerance.

RNAi-mediated down regulation of cyanogenic glycoside biosynthesis in cassava

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Cassava (*Manihot esculenta* Crantz) is an important tropical crop benefiting many people globally. It is preferred due to its attractive agronomical attributes. Its roots are a good source of starch, its leaves and tender shoots are eaten as vegetables and are an excellent source of vitamins, minerals and protein. Cassava is also used in the production of biofuel, animal feed and as a raw material for the starch industry. Sadly, cassava leaves and roots contain potentially toxic levels of cyanoglycosides, a demerit that generated interest in this study. That cassava is largely propagated clonally makes it ideal for improvement through genetic engineering. This study aimed at optimization of the regeneration protocol for Kenyan cassava varieties and generation of transgenic cassava plants with RNAi-mediated down regulated expression of the cytochrome P₄₅₀ genes (*CYP79D1/D2*). Three cassava genotypes: *Adhiambo Lera*, *Kibanda Meno* and *Serere* along with a model cultivar *TMS 60444* were used. As a prerequisite, an *in vitro* regeneration protocol was optimized for Kenyan cassava lines using immature leaf lobes. The transformable lines were then taken through *Agrobacterium*-mediated transformation with an RNAi cassette harbouring *CYP92D1* genes. Molecular analysis by PCR and RT-PCR confirmed transformation of the putative transformants. Analysis of cyanide content of the transgenic cassava lines correlated with the molecular analysis data. From this study an optimized transformation protocol for Kenyan cassava varieties was developed. Furthermore, transgenic cassava lines with cyanide content way below the cyanide content of the wild type relatives were produced. The results of this study disproves the view that African cassava genotypes are recalcitrant to *in vitro* manipulations. Production of transgenic lines with greatly reduced cyanide contents will further add value to cassava utilization. This is an impetus for further genetic manipulation of African cassava cultivars to mitigate the various genetic demerits associated with cassava.

Keywords: regeneration, transformation, cyanogenic glycosides.

Yield components analysis of sorghum (*Sorghum bicolor* L. Moench) for improvement of nutrition and livelihoods in Ghana

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Sorghum is an important staple crop in Ghana. The crop is used locally to prepare several meals such as 'tuo zaafi', porridge, cake or bread and may be cooked like rice. Despite the important role of sorghum in nutrition and the economy of Ghana, it attracts little research attention and the low economic yield of sorghum is a great disincentive to farmers. To improve the yield of the crop, there is a need to understand the yield components of existing local varieties. This paper evaluates and investigates the yield components of four local varieties of sorghum: Banina, Kadaga, Naga red and Kapala. The results revealed that significant variations were recorded among the yield traits studied. High values for phenotypic coefficient of variation and genotypic coefficient of variation was recorded for harvest index and number of grains per panicle. High heritability accompanied with high genetic advance was observed for the number of days to flowering, number of primary panicles, weight of grains per panicle, and days to maturity. The Banina variety produced the highest number of leaves, panicle height, panicle width, plant height, the number of grains per panicle, weight of grains per panicle, economic yield and biological yield. There was also a significant and positive correlation between characters studied. Principal components analysis revealed that Banina was the highest yielding variety and number of grains per panicle was the principal contributing factor to the high-yielding character of this variety. This indicates that local farmers could cultivate Banina to increase their yield and genetic improvement of number of grains per panicle by plant breeders could help to develop higher yielding varieties for enhancement of nutrition and livelihoods of the rural poor in Ghana.

Keywords: yield, yield components, sorghum, nutrition, livelihoods

Mapping the compositional and functional variability of small millets

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Small millets are regarded more highly than other cereals with regard to protein and mineral content. They are also considered to have therapeutic value against illnesses like diabetes but there is inadequate scientific evidence for this. Furthermore, the nutritional benefits may vary across varieties and geographical location. So research was undertaken in a project entitled "Revalorizing minor millets in rain-fed regions of South Asia" by The Post-Harvest Technology Centre, Tamil Nadu Agricultural University, India, on mapping the compositional and functional variability of small millets. It is a collaborative project anchored by the DHAN Foundation and the Canadian Mennonite University and supported under CIFSRF by IDRC and CIDA. The different small millet varieties were procured from the three project sites namely, Peraiyur block, Jamunamarathoor block and Anjetty block of Madurai, Thiruvannamalai and Krishnagiri Districts respectively, in Tamil Nadu with the support of the DHAN Foundation. The collected samples were analysed for their nutritional characteristics. The small millet variety from Jamunamarathur was rich in carbohydrate content. The protein content of the barnyard millet variety obtained from Peraiyur was found to be 8.52g/100g of the grains, which is essential for enzyme formation. The kodo millet grain variety from Coimbatore was found to be high in crude fibre (11.88g), which is best suited for diabetics and in iron content (62.31mg) which helps in haem formation. Finger millet was found to contain the maximum calcium content of 134.63g, which is essential for healthy bones and also reduces the onset of osteoporosis. Small millet grains were found to have promising quantities of essential amino acids such as tryptophan, cystine, methionine with high biological value crucial to health and growth. The nutritionally rich millet varieties were selected for the standardization of therapeutic foods (for diabetic, cardiovascular disease, obesity etc.) and traditional foods commonly consumed by the farmers.

Keywords: small millets, nutrition, therapeutic foods

Morphological and biochemical characterization of fruits from widespread common persimmon (*Diospyros virginiana* L.) seedlings

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Common persimmon (*Diospyros virginiana* L.) is native to the eastern United States, ranging from Connecticut to southern Florida, westward to east Texas and south-eastern Kansas and was introduced into various European regions. Fruits can be used in the food processing industry. It is also used as a rootstock for date plum grown in low temperature conditions. The aim of this work was to evaluate selected morphological and biochemical traits on 15 genotypes of Common persimmon grown in various localities of Europe. For experiments, we evaluated three cultivars of USA provenance (Weber, John Rick and Meader) which grew in Kyiv, Ukraine; one Ukrainian cultivar grew in Kyiv (Spacenko); six genotypes grew from seedlings in Kyiv (KY-01 to -06); two genotypes grew in Nova Kachovka, Ukraine (NK-01-02); one genotype grew in the botanical garden in Budapest, Hungary (BU-01) and one genotype grew in the arboretum in Mlynany, Slovakia (AM-01). We evaluated 50 technologically matured fruits from each genotype in 2011. For fruits, we evaluated weight (g), height and width (mm), number of seeds and other traits. We evaluated content of amino acids, content of macro- and micro-elements in fruit flesh, leaves and calyx. By the DPPH method, we evaluated antioxidant activity of fruit flesh in both methanolic and aqueous extracts. We evaluated the weight of fruits ranging from 3.78 g (AM-01) to 66.02 g (NK-03). Protein content ranged from 33.2 g.kg⁻¹ (fruits) to 218.4 g.kg⁻¹ (calyx). Fruits, seeds and calyx are characterized by higher content of valine, leucine, lysine, glutamine and arginine. We measured a high content of calcium in leaves and fruits (37.635/2.027 g.kg⁻¹), potassium (19.65/8.81 g.kg⁻¹) and magnesium (2.63/1.23 g.kg⁻¹). We measured antioxidation activity of fruit flesh in aqueous/methanolic extract which ranged from 52.47/51.13% to 91.48/93.66%. The results show, that common persimmon is a prospective species for adoption and use in many countries of Central and Eastern Europe.

Keywords: common persimmon, *Diospyros virginiana* L., fruits, amino acids, antioxidation activity, mineral element

Effect of shade drying on nutrient and phytochemical contents of *Mucuna pruriens* (agbara) and *Mucuna urens* (ukpo) leaves.

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Dark green vegetables are excellent sources of nutrients including phytochemicals and can be used to combat malnutrition. *Mucuna urens* and *Mucuna pruriens* are lesser known green leafy vegetables with an anti-anaemic property and other health benefits. The thrust of this work was to evaluate the nutrients, phytochemical and antinutrient composition of *Mucuna* leaves processed through shade drying. The leaves were sorted, washed, divided into two portions, one shade-dried and milled, the other blended in the fresh state. The nutrients, phytochemical and anti-nutrients of each sample were analysed using standard methods. The results indicated that protein, ash, fibre and carbohydrate contents of shade-dried *Mucuna pruriens* and *Mucuna urens* were higher compared to the fresh samples. However, *M. pruriens* values were higher than that of *M. urens*. The phytochemicals (beta-carotenes, flavonoids, polyphenols, saponins and alkaloids of shade-dried samples were high except glucosides which had values of 0.5-0.61mg/100g. *M. pruriens* and *M. urens* contain anti-nutrients including phytate, 2.49-2.50mg/100g (fresh samples) and 17.35-20.00mg/100g (shade-dried sample). Shade-drying increases the level of iodine and folate, thiamine and ascorbic acid but the increases were higher in *M. pruriens* than *M. urens*. *Mucuna pruriens* and *Mucuna urens* leaves have satisfactory and mostly comparable amounts of nutrient content. The phytochemicals of the leaves make them worthy of further investigation. However, shade-drying increased the nutrients and anti-nutrient content of the leaves although not to a toxic level, except for phytate.

Keywords: malnutrition , *Mucuna pruriens*, *Mucuna urens*, phytochemical, shade-drying

Differences of fruit morphology and nutrient composition of baobab fruits from eastern and coastal Kenya

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Baobab (*Adansonia digitata L.*) is an indigenous fruit tree in sub-Saharan Africa (SSA). It is a multipurpose, drought-tolerant species and its fruits contain valuable nutrients, which can contribute to combatting malnutrition in African drylands. Our recent review study on the nutrient composition of ten indigenous fruits in SSA showed a huge variability of the published data. Regarding baobab, the review showed in addition a lack of information about baobab in Kenya. In the present study we evaluated the variability of morphological characteristics and nutritional composition of baobab fruits aiming at selecting superior mother trees for future domestication programmes. Along a transect from Eastern to Coastal Kenya, 64 individual baobab trees were sampled at 11 locations from September to December 2012. For each of the trees, GPS locations were documented, tree characteristics measured and 5-10 fruits randomly sampled. Morphological characteristics of the fruits were assessed, including fruit shape, weight and length as well as colour and weight of pulp and seeds. In addition, selected nutrient components including contents of water, vitamin C, total acidity, sugar and selected minerals are being analysed. The most frequent fruit shape was ellipsoid, but some trees also had globose, oblong or ovate fruits. Fruit length varied considerably and ranged from 6.6 to 36 cm (individual fruit minimum from Kibwezi, maximum from the Malindi area). Additionally the fruit weight showed huge differences, with one fruit from the Voi area showing the lowest (20g) and another from the Kilifi area the highest weight (713g). Similarly, pulp weight per fruit ranged from 6 to 125g. Nutrient analyses are currently being undertaken to assess whether the detected tree-to-tree variability of morphological traits is also reflected in fruit nutrient components. Results of this study will be useful for future domestication programmes and for promoting consumption of these valuable indigenous fruits.

Keywords: domestication, genetic diversity, nutrition, physico-chemical characteristics

The yam food a solution for the food crisis and famine in Africa

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Africa is characterized by an under-nutrition food crisis and famine in most homes. This could be due to major food crops being under threat - cassava, maize and bananas have been attacked by deadly diseases. Also, it is also due to replacement of land for food crops by biofuels, sugarcane, cotton and sunflowers. Furthermore, crop failure can be due to prolonged droughts, heavy rains, and crop pests but food insecurity is also due to neglect of traditional food reserve crops such as yam (*Dioscorea* spp.).

In 2010, a yam food promotion project was founded after envisaging that the yam had prospects of being a saviour for food insecurity not only in sub-Saharan Africa but also globally. This is evidenced by the crop supporting the most populated countries in Africa i.e. Nigeria (150 million). It also contributes more than 200 calories per person per day for more than 150 million people in West Africa alone which comprises more than a third of the total population in the sub-Saharan region. This has prompted even the most populous nations in the world to seek importation of yam from Nigeria to the tune of 200,000 metric tonnes per year. The yam has also not been visited by major diseases and in most areas of eastern and central Africa, it still grows widely. In the East African countries it has historically been taken as a traditional reserve crop. Not only is it just a food secure crop but it has immense nutritional and medicinal values. To conclude, the yam crop calls for a unified African voice and respect as a vital neglected and underutilized species.

***Moringa* production as a way out for malnutrition in Africa**

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Malnutrition is now a common phenomenon in most African countries. Child malnutrition is a situation by which a child's intake of nutrients (protein, fat, vitamins and minerals etc.) is insufficient to sustain the needs of his or her body. As it is referred to here, malnutrition originates from a situation of having no access to vitamin-rich foods and lack of economic capacity to purchase same. According to the United Nations Food and Agriculture Organization (FAO) it is estimated that nearly 870 million people, or one in eight people in the world were suffering from chronic undernourishment in 2010-2012. Almost all the hungry people, 852 million, live in developing countries, representing 15% of the population of developing countries. There are 16 million people undernourished in developed countries (FAO, 2012). Twenty six percent of undernourished children live in Africa.

To combat the aforementioned situation, African leaders should embark on a policy to promote the production and uses of *Moringa oleifera* in all African nations. *Moringa*, one of the most underutilized crops in Africa, is known as a miracle tree and is found in Africa, Central and South America, Sri Lanka, India, Malaysia and the Philippines. This tree is little known in the western world for its nutritional value. In developing tropical countries, *Moringa* trees have been used to combat malnutrition, especially among infants and nursing mothers.

According to Optima of Africa Ltd., which also for a long time has worked with the tree in Tanzania, 25 grams daily of *Moringa* leaf powder will give a child the following recommended daily allowance; protein 42%, calcium 125%, magnesium 61%, potassium 41%, iron 7%, vitamin A 272% and vitamin C 22%. *Moringa* is medically used as a prevention and treatment. As it is scientifically proved, if each household in Africa could plant a *Moringa* tree, millions of African children would be safe, sound and medically ok.

Morphological characteristics and antioxidant activity of flowers and fruit from oil pumpkin (*Cucurbita pepo* var. *styriaca*) and giant pumpkin (*Cucurbita maxima* L.)

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Pumpkins are considered as the most exploited species in human nutrition in many countries around the world. Fruits and seeds are mostly processed for foods and pharmaceuticals preparation. Also flowers, calyx, stamens and juvenile fruits are very valuable sources of biologically active substances. The aim of this work is to compare two types of pumpkins: giant pumpkin (*Cucurbita maxima* L.) and oil pumpkin (*Cucurbita pepo* var. *styriaca*) with regard to morphological characteristics of flowers, fruits and their antioxidant activity from species mostly cultivated in Central and Eastern Europe. Harvesting of flowers and fruits and their separation of basic parts were mechanically processed. Regarding fruits, juvenile fruits were evaluated in nine weight categories (A-I). Antioxidant activity was determined by the DPPH method (Brand-Williams et al., 1995). For evaluation of flowers of *C. pepo* and *C. maxima*, we determined the average weight of fresh flowers in the range 4.13g/6.18 g, crowns 2.95g /4.40g, calyx 0.84/1.55g and stamens 0.29g/0.42g. We determined the average dry matter content of flowers to be 8.96%/8.59%. Average antioxidant activity of fresh flowers in aqueous extracts was 6.23%/25.59% for *C. pepo*/*C. maxima* and for dry flowers 38.52 %/35.86%. For fresh flowers, we determined antioxidant activity in methanolic extracts to be 10.80%/22.56% and for dry flowers 73.71%/50.00%. For the male flowers we determined a higher antioxidant activity than for the female flowers. With the exception of pulp and seeds, also exocarp and placenta are important raw material for practical use. Beside the valuable biochemical composition of exocarp and placenta they are also characterized by valuable antioxidant activity.

Keywords: giant pumpkin, *Cucurbita maxima* L., oil pumpkin, *Cucurbita pepo* var. *styriaca*, flowers, fruits, calyx, crown, antioxidant activity

Comparison of quince (*Cydonia oblonga* Mill.) and Chinese quince (*Pseudocydonia sinensis* Schneid.): morphological and antioxidant characteristics

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Quince (*Cydonia oblonga* Mill.) is a fruit species, whose fruits have a high therapeutic value and that is why they are used in many countries in traditional medicine. Chinese quince (*Pseudocydonia sinensis* Schneid.) is a lesser used species, although it is a relative of quince. The aim of the study was to evaluate some morphological characters of both kinds of fruit and antioxidant activity of morphological parts of the fruit. For these experiments, two genotypes were used from each species growing in the Arboretum Mlyňany (Slovakia). We determined the antioxidant activity of different parts by the DPPH method. (Yokozawa et al., 2000).

In the genotypes from the evaluated species *C. oblonga/P. sinensis* we determined the average weight of the fruit in the fresh condition to be in the range 147.61 – 253.27g/197.85 – 466.38g, the exocarp weight 28.50 – 43.89g/24.85 – 45.10g, the mesocarp weight 116.36 – 204.99g/160.30 – 389.80g, the seed weight 1.05 – 1.54g/9.22 – 17.42g, the height of fruit 74.09 – 80.88mm/98.06 – 124.48mm, average of fruit 60.11 – 81.51mm/62.33 – 88.64mm. In aqueous extracts we determined antioxidant activity of the species *C. oblonga/P. sinensis* in dry mesocarp in the range 43.52 – 67.73%/52.76 – 82.20%, in fresh mesocarp 7.36 – 14.78%/15.30 – 23.50%, in dry mesocarp 30.92 – 41.30%/41.68 – 50.15% and dry endocarp 55.19 – 76.44%/91.20 – 92.72%. We determined antioxidant activity in methanolic extracts of the species *C. oblonga/P. sinensis* in dry exocarp in the range 93.29 – 93.32%/91.87 – 93.25%, in fresh mesocarp 10.29 – 36.0%/17.10 – 17.11%, in dry mesocarp 54.55 – 74.11%/80.39 – 84.11% and in dry endocarp 95.14 – 95.39%/94.97 – 95.62%. Results document that the fruits of both species can be practically used in the preparation of many dishes, while they can be used as raw material for pharmaceutical and cosmetic use.

Keywords: quince, *Cydonia oblonga* Mill., Chinese quince, *Pseudocydonia sinensis* Schneid., antioxidant activity, mass, height, width, exocarp, mesocarp, endocarp

Morphological and antioxidant characteristics of *Ziziphus jujuba* (Mill.) fruit

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For the countries of Central and Eastern Europe, *Ziziphus jujuba* (Mill.) represents an unknown species. Usually, it is grown only in botanical gardens or arboreta. Recently, this plant has become the object of research in many workplaces for high nutritional and therapeutic value of its fruit and adaptability to difficult growing conditions. The objective of this study was to evaluate genetic resources of *Ziziphus jujuba* fruit collections, focusing on their morphological characteristics and antioxidant activity. In our study, we have evaluated the fruits of 28 genetic resources obtained from the Research Unit in New Kachovka at Nikitsky Botanical Garden in Yalta. Antioxidant activity was determined using the DPPH method used by Brand-Williams et al. (1995) and Kutlu et al. (2011). Evaluating the results obtained, we have found the average weight of fruit in the range from 2.92 g (ZJ-2/1) to 14.10 g (ZJ-1/15), the amount of fruit 19.52 mm (ZJ-3/9) - 41.01 mm (ZJ-1/25) and width of fruit in the range from 15.30 mm (ZJ-2/1) to 28.49 mm (ZJ-1/15). Using variance analysis, we have confirmed significant differences between genotypes in all characteristics. For the fruit weight, we have determined, for the vast majority of genotypes, a middle level of variability, while for height and width of the fruit we have determined a very low degree of variability. Antioxidant activity was determined in water extracts in the range from 11.08% (ZJ-3/11) to 67.42% (ZJ-1/5) and methanolic extracts in the range from 5.88% (ZJ-3/11) to 31.72% (ZJ-2/18) In general, genotypes showed higher antioxidant activity in the water extracts than in the methanol extracts.

Keywords: *Ziziphus jujuba* Mill, fruits, weight, height, width, antioxidant activity, water

Nutritional value of desert date tree products in Uganda

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The desert date (*Balanites aegyptiaca*, Del. L.) is one of the neglected trees of growing importance in the drought and famine-prone areas of Uganda. The tree produces edible leaves and fruits relied upon by dryland communities. Unfortunately, information on its nutritional composition is still lacking, thus limiting recommendations for their wider use and promotion. This study was designed to determine the nutritional composition of different parts of *B. aegyptiaca* consumed by different communities in Uganda. Samples were collected from the Katakwi, Adjumani and Moroto districts in Uganda for nutritional evaluation. Dry matter content of the leaves, flowers and fruit pulp ranged from 95% in fruit pulp to 98% in leaves and flowers. Ash content of the leaves and flowers was 8.07%, while that of the fruit pulp was 6.97%. Fat content of the leaves (2.29%) was significantly higher than that in fruit pulp (0.37%). Similarly, crude protein content was greater in the leaves and flowers (16.95%) than in the fruit pulp (5.4%). The leaves and flowers were generally richer in macronutrients than in fruit pulp in the order of K>Na>Mg with mean values of 19.54, 3.32 and 1.26 mg g⁻¹. Iron was the most abundant micronutrient in all *Balanites* parts investigated. This was followed by Mn, Zn and Cu with mean values of 452.21, 60.65, 35.69 and 25.49 µg g⁻¹, respectively. A similar trend was found in fruit pulp. There is a need, however, to determine the level of anti-nutritional factors in *Balanites* products and the effect of different leaf preparation methods on nutrient availability to further guide their wide usage.

Keywords: *Balanites aegyptiaca*, crude fat, dry matter, crude protein, mineral content

Theme 2: Upgrading value chains of neglected and underutilized species

Heat pump drying of neglected and underutilized species: status, potentials and applications

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Neglected and underutilized species play an important role in the subsistence and economy of poor people throughout the developing world because of their food, fibre, fodder, oil, nutritional or medicinal values. However, many of these neglected and underutilized species including herbs, spices and vegetables naturally possess high moisture content which ought to be reduced to prevent proliferation of bacteria and enhance ease of handling and less space for storage, resulting in reduced handling costs. However, drying is an energy-intensive process and different drying techniques require modification/adaptation based on the biomaterial that is dried. In this paper, heat pump drying technology was discussed to give relevant information on its unique importance for drying of these high-quality temperature-sensitive products. In view of the fact that many potential users view heat pump drying technology as fragile, slow and highly capital intensive when compared with other hot air convection dryers, the paper tried to divulge the principles and potentials of heat pump drying technology and the conditions for its optimum use. Also, the processes responsible for loss of quality during the drying of neglected and underutilized foods were identified while features of heat pump drying technology that help in controlling the identified cases were highlighted. Moreover, recent cases of applications of heat pump drying to neglected and underutilized species are presented. In conclusion, in all the cases described, heat pump drying was found to be applicable to herb and spice drying and gave better drying time and quality than products dried with hot air drying. There were higher product outputs and low energy consumption due to a high Specific Moisture Extraction Ratio and Coefficient of Performance. The identified potentials of heat pump drying include unique drying environments for new products and added value, high system efficiency and reliability, low environmental impact, and ease of use.

Keywords: heat pump dryer, herbs, spices, quality, drying characteristics

Mobilizing farmers towards promotion of orphan crops in Malawi

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Orphan crops such as bambara nut, pumpkins, okra and amaranth are a significant source of food and income in rural areas despite receiving little attention from agricultural institutions and policy. It is therefore argued that promotion of orphan crops is one of the significant steps to improving livelihoods of rural Malawians. One of the main approaches for involving farmers in promoting orphan crops is the use of existing farmer organizations. However the important question arises as to what it would take for farmer organizations to successfully promote orphan crops in Malawi. This paper concludes that the factors that need critical consideration in the process of using farmer organizations to promote orphan crops include organizational factors related to formation process, operational capital and environment of the organizations. The characteristics of members related to their period of membership, knowledge of rules, participation in activities and decision-making as well as their trust in fellow members are equally important for farmer organizations to promote orphan crops. Otherwise, the farmer organizations would only promote orphan crops at subsistence level to attain food security with very little commercialization of orphan crops for improved income in rural areas.

Keywords: orphan crops, farmer organizations, organizational factors, socio-economic characteristics of members

Utilizing social capital to upscale orphan crops in Malawi

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National agricultural institutions and policies have neglected orphan crops such as bambara nut, pumpkins, okra and amaranth. Yet smallholder farmers continue to rely on these crops for sustaining their household food security and income. Interventions aiming at up-scaling orphan crops with involvement of smallholder farmers are therefore critical for rural livelihoods. Utilizing social capital in the form of smallholder farmer groups has been advocated as an inevitable means to up-scaling orphan crops. However, very little empirical information existed on the use of social capital to up-scale orphan crops in Malawi. This paper provides findings on farmer groups' preferences, strengths, opportunities and challenges for up-scaling orphan crops. The study reveals that farmer groups' preferences on type of orphan crops to up-scale are site specific. However, orphan crops such as sweet potato, sorghum, bambara nut, pumpkins, okra and amaranth are preferred across sites. Results also show that high member representation, effective communication, existence of rules, efficient conflict management mechanisms, simple authority structures, semi-autonomous decision making and capability of leaders as strengths of farmer groups in up-scaling orphan crops. Opportunities existing for farmer groups to up-scale orphan crops include availability of land, water sources and indigenous knowledge on husbandry and utilization of orphan crops. Challenges hindering their ability to up-scale orphan crops include unavailability of adequate production inputs, markets and knowledge of modern practices for improving productivity as well as post-harvest handling of orphan crops. It is recommended that for farmer groups to successfully utilize their strengths and existing opportunities in up-scaling orphan crops, there is a need for building their capacity. Capacity building should focus on training farmer groups on husbandry, post-harvest handling, processing and marketing of orphan crops. The farmer groups should be oriented towards business. This will enable them to generate income needed for sourcing inputs essential for up-scaling orphan crops.

Keywords: social capital, orphan crops, up-scaling, preferences, opportunities, challenges, farmer groups

Upgrading value chains of neglected and underutilized plant species experience and lessons learnt in Sri Lanka

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Sri Lanka, being a global biodiversity hotspot, is well-known for its unique agricultural ecosystems. The existence of hundreds of 'minor' species, which are grown, reared or collected particularly in marginal environments, and commonly termed as neglected or underutilized species (NUS), is a key characteristic of these ecosystems. However, a huge gap exists with respect to the development of a well functioning marketing system to mainstream such species into the domestic food markets. This study intuitively shed light on the development of possible value chains for agro-biodiversity-sourced food products primarily involving NUS in Sri Lanka, which is one of the key objectives of an extensive multi-country research program concurrently underway in Brazil, Kenya, Sri Lanka and Turkey under the coordination of Bioersity International, UNEP and FAO. Participatory Rural Approaches were employed with a cross-section of purposively selected households (n>200) located in two major agro-biodiversity systems in Sri Lanka where the NUS are predominant, to better understand dynamics, gauge performance, improve functioning and develop systems of agro-biodiversity-sourced food product marketing. The outcome of analyses, based on the conceptual framework consisting of three major domains (covering *inter alia* Production, Channel, and Consumption), revealed that, unlike commodity crops, NUS have a non-existent or poorly organized marketing system and value chain at present that are mostly confined to rural farmer markets and medicinal purposes. This stresses the importance of a holistic domestic and international approach to bring such species under cultivation and at the same time of re-governing the markets in order to bring sustainable benefits to the poor consumer communities.

Keywords: agricultural marketing, agro-biodiversity, food and nutrition security, neglected and underutilized species, livelihood development

Analysis of the pigeon pea (*Cajanus cajan* (L.) Millsp.) value chain for increased productivity and improved livelihoods for smallholder farmers

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Pigeon pea (*Cajanus cajan* (L.) Millsp. is the third most important legume in Kenya after beans and cowpea. The crop is cultivated largely by small-scale farmers in the arid and semi-arid lands that are characterized by high rainfall variability. Understanding market requirements for crop improvement is important as the varieties must possess the desired pre-and post-harvest traits as defined by stakeholders in the value chain. The purpose of this study was to investigate the various stakeholders, marketing constraints, and characteristics of the market-preferred pigeon pea varieties so as to improve the productivity of the pigeon pea subsector in Kenya. Key informant surveys, semi-structured questionnaires, analysis of secondary data and literature reviews were tools used in the study. Using cytoplasmic male sterile technology, high-yielding pigeon pea hybrids that are medium maturing were developed. The unavailability of quality seed in sufficient quantities of high-yielding varieties was cited as the main factor negatively affecting pigeon pea production hence hampering exploitation of both domestic and export markets. In addition, markets and marketing channels were found to be fragmented, uncoordinated and characterized by a large number of intermediaries that reduce profits for farmers. The breeding program worked closely with, farmers, the Kenya Agricultural Research Institute, the International Crops Research Institute for the Semi-Arid Tropics, and the Leldet Seed Company. The hybrid seed is expected to lead to evolution of business partnerships with private seed companies, processors and exporters. The partnerships are expected to enable direct contractual agreements with farmers to produce the desired grain and volumes for both domestic and export markets. This in turn will minimize the number of middlemen, shorten the value chain and hence improve livelihoods for smallholder farmers.

Keywords: pigeon pea, stakeholder analysis, value chain

Marketing and contribution of pepper fruit (*Dennettia tripetala*) to rural household income in the rainforest belt of Nigeria

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Pepper fruit (*Dennettia tripetala*) is a tropical spice fruit localized in the rain forest belt of Nigeria. When in season (rainy season), it is collected and marketed by rural households as a source of income and for other cultural purposes. The study was carried out to assess the marketing pattern of pepper fruit and the contribution to the total household income of collector households. A multistage sampling technique was used to select a total of 317 collector households from Edo and Delta States, South-South Nigeria. Household, community and marketing data were elicited using interview guides. Descriptive and inferential statistics were used in the analyses of data. The study found that collection is dominated by women (91%) and the average age of the collectors was 46.2 years. Marketing activities are highly specialized: about 84% of the collector households were not involved in village level marketing of pepper fruit and farm gate sale accounted for over 92% of total collection. Income from sale of pepper fruit represented between 2.63 to 17.2% of total household income in the fruit season months (May and June). About 44.3% of the income is utilized in meeting household food needs. Age of the household head, dependency ratio, number of years in the community, sex, farm income, presence of markets in communities and distance to collection locations were factors that influence rural household dependence on income from pepper fruit collection. The study recommends that collectors should take advantage of specialized urban (fruits) markets; this would be facilitated through improvement in rural roads and market infrastructure which can help reduce the transaction costs associated with marketing.

Commercialization of underutilized plants in Uganda: an analysis of the market chains of *Cyphomandra betacea* L. in Uganda

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Cyphomandra betacea L. also known as tree tomato or tamarillo, is a fast-growing fruit tree species belonging to the Solanaceae family. It is believed to have originated from the Andean region but has since been introduced to tropical Africa. The plant is economically important for its nutritional, medicinal and market values. In Uganda, this species has for long been growing in home yards with little attention. Tree tomato was recently identified as a priority species with potential for commercialization in Uganda. However, information on its value chain, demand, supply and economic potential in Uganda is non-existent. This study aimed to document and characterize the plant's value chain, assess its demand and supply dynamics and evaluate the economic potential of the plant's trade in Uganda. Primary and secondary data were collected via a market survey, focus group discussions, field observations and interviews with key informants. A market survey was conducted in seven major markets in Kampala and focus group discussions held with key tree tomato value chain actors. The value chain of the tree tomato consists of farmers, transporters, wholesalers, retailers, processors, exporters and consumers as major actors. The major tree tomato product on the domestic market is fresh fruits. Internationally, demand for processed tree tomato products from Uganda like pulp, is emerging in Europe. The value chain is characterized by a lack of market information, inappropriate technologies for processing and absence of extension services. Demand for *C. betacea* products is high in Uganda and emerging in Europe. Supply, however, is still low and insufficient to meet current demand. Trade in the plant's products contributes 10% to the respective traders' incomes. Promoting large-scale production, investing in fruit processing and value addition, organization of the value chain actors and provision of market information are essential for successful commercialization of tree tomato in Uganda.

Keywords: neglected plants, value chains, commercialization, tree tomato, Uganda

Sensory evaluation of sweet potato and wheat flour blends in pan bread

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Sweet potato (*Ipomoea batatas*) serves as an important food security crop in parts of Kenya and is becoming an important cash crop. It is one of the world's high-yielding crops in terms of production per unit area. Researchers at KARI-Njoro have developed and recently released orange-fleshed sweet potato varieties that are high in beta-carotene yield and dry matter and tolerant to diseases and pests. The new varieties have potential for combatting widespread vitamin A deficiency in Kenya. Kenya has a deficit of about 600,000 metric tonnes of wheat of which 95% is needed for production of common bread. Sweet potato flour could be blended with wheat flour and be used for bread production to reduce the deficit and combat vitamin A deficiency. This study aimed to develop pan bread from the orange-fleshed sweet potato variety KENSPOT 5 which has 4.7µg/g beta-carotene. Sweet potato/wheat flour pan bread was made and sensory evaluated by 20 untrained panelists, randomly selected from KARI-Njoro. The panelists evaluated the product for appearance, taste, flavour, colour, texture and general acceptability on a 5-point hedonic scale. Data analysis showed no significant difference ($P>0.05$) in all the attributes. However, it was noted from the means that panelists preferred the taste and colour of bread with low sweet potato content (10%). Bread containing 10% sweet potato had the highest means in texture while the 100% wheat flour pan bread had almost the lowest mean. It was concluded that all the pan breads containing sweet potato flour (10%, 20%, 30% and 40%) were acceptable but those with a lower content of sweet potato flour were preferred. The fact that the pan breads were acceptable to the consumers indicates the feasibility of it gaining popularity and market. As a result of the study, a blend of 10% and 90% sweet potato and wheat flour respectively is recommended for quality pan bread.

Keywords: pan bread, sweet potato, sensory evaluation.

Policies and strategies to improve the utilization of *Blighia sapida* (K Konig) in the rainforest and savannah ecological zones of Nigeria

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This paper takes a critical look at policies and strategies that can be used to improve the utilization of *Blighia sapida* (ackee) fruits to reduce poverty in the rainforest and savannah ecological zones of Nigeria. Semi-structured questionnaires were used to collect information on the indigenous uses of *B. sapida* in the two ecological zones. Two communities in each ecological zone were purposely selected. Fifty respondents in each sampled community were randomly selected to investigate the indigenous uses of *B. sapida* in the two ecological zones. The results of the study (chi-squared test) showed that a significant difference exists ($P < 0.05$) in the indigenous uses of *B. sapida* in the two ecological zones. There is however the need to harmonize the indigenous uses of *B. sapida* in order to optimize the utilization of the species. In the light of this, it is essential that policies that will help to promote the utilization of *B. sapida* and other neglected or underutilized species (NUS) be enshrined in the forest policy statement of the states covered by the study. Promoting the conservation of NUS plants should also be included in the forest policy statement of the states covered by the study. An NUS unit in the State Forestry Departments in the country should be created that will help to promote the utilization of *B. sapida* and other NUS plants all over the country through proper and prompt dissemination of information. Other strategies that can help to promote the utilization of *B. sapida* include; commercialization of *B. sapida*, value addition to the fruits of *B. sapida*, selling the fruits in urban markets as well as exporting the fruits in order to improve income earnings from the fruits.

Keywords: policies, strategies, *Blighia sapida*, rainforest and savannah

Diversification and valorization of non-timber forest products of plant resources in the Torodi Department (Niger, West Africa): social variation and implications for perspectives policies

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Interest in research on non-timber forest products (NTFPs) has been growing in the last decade due to their contribution for sustainably improving livelihoods. In this respect, an assessment of diversity of plant NTFPs was carried out in the Torodi department, located in the country of Niger. The study was aimed to 1) inventory the plant's NTFPs and their uses, 2) assess inter- and intra-cultural variation about the knowledge related to their use, and 3) identify how local people value NTFPs in this area. Structured interviews were conducted with 227 randomly selected individuals from four villages and four main socio-cultural groups: Peulh, Zarma, Gourmantché and Haoussa. Focus group discussions were organized to check information collected during the structured interviews. Local markets were visited to understand how NTFPs were valued, what NTFPs are sold, what quantities of NTFPs are sold and which actors are involved. Collected data were processed and analysed using graphs and statistical analyses. Results showed that 43 plants, belonging to 24 families are used by local people as NTFPs in Torodi. Mimosaceae, Capparaceae and Cesalpiniaceae are the most important plant families used as food. NTFPs of *Vitellaria paradoxa*, *Adansonia digitata*, *Balanites aegyptiaca*, *Combretum nigricans* and *Acacia senegal* are the most preferred by men while women used mostly *Adansonia digitata*, *Vitellaria paradoxa*, *Cassia tora*, *Corchorus tridens* and *Ceratotherca sesamoides* in descending order of importance. However, differences between investigated socio-cultural groups were not significant. Moreover, market investigation showed that marketing of leaves of *Adansonia digitata* deserves the most attention and its marketing chain study revealed several stakeholders such as farmers, wholesalers, speculators, retailers and consumers. Perspectives policies for food security in this area will include valorization of the main NTFPs and particularly value chain studies of leaf marketing of *Adansonia digitata*.

Keywords: non-timber forest products, marketing chain, *Adansonia digitata*, Niger

Boosting female farmers' income from "otiru" production in Nigeria: the value chain approach

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"Otiru" is a condiment produced from fermented underutilized African yam bean seeds (AYB) (*Sphenostylis stenocarpa*). AYB is one of the most important tuberous legumes of tropical Africa. It is cultivated as a secondary crop with yam in Ghana and Nigeria. The seed and tubers are the two major organs of immense economic importance as food for Africans. This underutilized crop has huge potential for food security in Africa. It was observed that AYB is well balanced in essential amino acids. "Otiru" was produced by natural fermentation of the seeds. It was soaked in water overnight then boiled for 2 hours and dehulled to remove the anti-nutritional factors and fermented naturally for 24 hours, 48 hours and 72 hours. It was observed that AYB fermented for 72 hours had the highest protein content of 34% compared to the raw product (27%) and there was a reduction in the anti-nutritional factors of the seeds at different times of fermentation. It was also discovered that "otiru" was preferred to the common "iru" produced from African locust bean seeds which is very difficult to produce. Condiments are one of the major income-generating businesses involving market women in Nigeria and condiment production is limited because of the long cooking time of 12 hours prior to fermentation, unlike African yam bean seeds which can be cooked for 2 hours after soaking. Women are the major group that will be involved in the value-chain production of "otiru". The female farmer will plant the seeds and harvest them, while the market women group will be involved in the processing and production of "otiru" which can then be packaged either wet fermented, dry or in a milled form for marketing purposes thus improving food security by solving the problem of protein/energy malnutrition and helping to contribute to wealth creation in the country.

Keywords: African yam bean seeds, otiru, value chain

Functional properties and sensory quality of fermented cocoyam (*Xanthosoma sagittifolium*) flour and its cooked paste

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Cocoyam (*Xanthosoma sagittifolium*) was processed into fermented flour using three different steeping times (12, 24 and 36 h) and three oven-drying temperatures (50, 60, 70°C) in a 3 by 3 factorial design. Sun-dried samples were used as control. Fermented cocoyam flour samples were analysed for functional properties: water absorption capacity (WAC), bulk density (BD), dispersibility, water solubility index (WSI) and pasting properties. All analyses were done in triplicate and effect of steeping time and drying temperature were studied. The flour was cooked into paste and was subjected to sensory evaluation using a 9 point Hedonic scale. Steeping times and drying temperatures generally had significant effects ($P < 0.05$) on WAC, BD, dispersibility, WSI and paste viscosities. However, steeping times and drying temperatures did not have a significant effect ($P > 0.05$) on peak time and pasting temperature. The result of WAC, BD, dispersibility, WSI ranges were 1.11g/g – 1.73g/g, 0.72g/ml – 0.9g/ml, 25.50% - 34.50%, 5.92% - 10.36% respectively. Flour produced by steeping for 36 h, oven dried at 50°C had the highest peak (270.21RVU), trough (205.75RVU), breakdown (68.59RVU), final (317.17RVU) and setback (111.42RVU) viscosities. Cooked paste from fermented cocoyam flour processed by steeping for 36 hours was highly rated by sensory assessors and there was no significant difference ($P > 0.05$) in their colour, texture and aroma. Steeping for 36 hours and oven-drying at 50°C could be adopted for production of fermented flour from cocoyam (*Xanthosoma sagittifolium*) for an acceptable cooked paste.

Production and quality evaluation of mixed fruit jam made from African star apple (*Chrysophyllum albidum*) and tamarind (*Tamarindus indica*) using different blend ratios

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Mixed fruit jam was produced from a composite of two underutilized fruits, African star apple (*Chrysophyllum albidum*) and tamarind (*Tamarindus indica*) using different blending ratios on a w/w basis by the open kettle method. Blending ratios of African star apple/tamarind used were ABC (100:0); DEF (75:25); GHI (50:50); JKL (25:75) respectively. African star apple, a high pectin content fruit, was blended with tamarind, a low pectin content fruit, to create a synergy for gel stability. Chemical analysis (pH, total soluble solids, total titratable acidity, moisture content, total acidity and ash) was performed as an index of quality status for different blend ratios. Results obtained showed pH ranged from 3.2- 3.4, total soluble solids (65-68° Brix), total titratable acidity (0.057 - 0.074), moisture content (22.6 - 29.8%), total solids (70.2-77.4%) and ash (1.0-2.2%). Changes in pH and total soluble solids with time monitored weekly over a three week period were within the range of 3.2-3.5 for pH and 65- 68° Brix respectively. Ten semi-trained panelists determined the following consumer acceptability parameters (colour, flavour, taste, spreadability and general acceptability) as an index of quality status of different blend ratios. It was generally observed that consumer acceptability had an inverse relationship with increased blend ratios of tamarind. African star apple without any composite mixture was preferred amongst all samples for all parameters determined.

Keywords: African star apple, tamarind, blend ratios, consumer acceptability, quality

Market chain analysis of velvet tamarind (*Dialium guineense* Willd.) products in Ghana

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Underutilized crops are now being presented as 'new crops' by virtue of the fact that commercial companies and researchers are only recently working on them. They are important as they allow improvement of livelihoods by generating income, supporting food security and improving nutrition. People in Ghana depend on a number of tree species such as velvet tamarind. The overall objective of this research was to obtain insight in the structure and functioning of the markets of velvet tamarind products in Ghana. The present study first identified all chain actors involved in the market of velvet tamarind in Ghana namely gatherers, traders, processors and consumers and described their characteristics, activities, problems and linkages. Secondly, the markets of three different velvet tamarind products traded in Ghana were mapped. Then the different market chains and their characteristics were analysed at local and national levels. Finally, recommendations were formulated on how local chain development should build linkages and enhance trust between actors in the market chain. Once the major domestic limitations have been tackled, commercialization of velvet tamarind products could be developed and expanded.

Keywords: value chain, market actors, products, velvet tamarind, Ghana

Socio-economic determinants of *Corchorus olitorus* and *Telfairia occidentalis* demand in Osun State, Nigeria: implications for local value chain upgrading

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Corchorus olitorus and *Telfairia occidentalis* constitute significant components of the indigenous cuisine in south-western Nigeria. The socio-economic determinants of consumer demand for both neglected and underutilized vegetable species (NUS) in Osun State in Nigeria were investigated. A multi-stage random sampling technique was adopted to select households in the study area and data were collected through the use of well structured questionnaires. Information was collected on household socio-economic and demographic characteristics such as age, gender, household size, level of education, income level, occupational status of household head, as well as household expenditure on *Corchorus olitorus* and *Telfairia occidentalis* using seven days memory recall, total household expenditure including food expenditure and non-food expenditure, quantities of *Corchorus olitorus* and *T. occidentalis* purchased and so on. The study revealed that age, marital status, level of education, and monthly income of household heads are strong determinants of household demand for *C. olitorus* and *T. occidentalis* across the study area, in various patterns. The implications of the observed patterns for upgrading the value chains of both crops are outlined. Strategies to enhance consumer awareness of their nutritional significance and increase the household demand for the two crops are suggested.

Keywords: *Corchorus olitorus*, *Telfairia occidentalis*, household demand, determinants, value chain.

Assessment of gender participation in underutilized indigenous vegetable production and farmers' savings profile in South-west Nigeria: implications for poverty alleviation in Nigeria

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The study assessed the gender differences in participation along vegetable production chains and the savings profile of underutilized indigenous vegetable farmers participating in the Ni-CanVeg Project¹ in South-west Nigeria. A total of 52 participating farmers comprising 35 women and 17 men, were sampled from four purposely selected vegetable farmers' communities across four States in Southwest Nigeria. A structured and participatory interview schedule consisting of open- and closed-ended questions was used. Results showed that the mean age of the male underutilized vegetable farmers was 48.0±9.02 years while that of the females was 51.3±9.96 years. Also, 68.1 per cent of women acquired farmland through their husband while only 13.5 per cent of men showed that they acquired farmland through purchase. Of women and men, 66.7% and 12.7%, respectively indicated that they used their male children for stumping while 65.3 percent of females participated in harvesting but only 14.9 percent of males participated in harvesting. Results further showed that women also spent \$48.6 on social activities while men spent \$32.7 but with women saving \$34.9 and men only save \$17.6 monthly. Results of Chi Squared analysis showed significant associations between gender and land acquisition/ownership ($X^2=15.05$; $P\leq 0.05$); land clearing ($X^2=36.19$; $P\leq 0.01$); planting ($X^2=4.708$; $P\leq 0.03$); harvesting ($X^2=51.12$; $P\leq 0.05$) and marketing of underutilized vegetables ($X^2=17.03$; $P\leq 0.05$). The study concludes that women underutilized vegetable farmers in Southwest Nigeria save more than their male counterparts but have limited access to land. It is therefore recommended that the project should intensify efforts in educating the men on the need to give women access to land with a view to expanding production and marketing of farm produce, especially underutilized vegetables, and hence alleviating poverty among the farmers.

Keywords: indigenous, underutilized, vegetables, poverty

¹IDRC/CIDA Project to popularise the production, processing and consumption of underutilized/neglected indigenous vegetables in South-west Nigeria.

₦160 to \$1US (conversion rate of naira to dollar).

Theme 3: Creating an enabling policy environment

Principal component analysis of cocoyam production in Western Nigeria

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This study determined the major components of cocoyam production in Western Nigeria. Principal component analysis was employed to determine the key determinant of cocoyam production in the study area. A multi-stage sampling technique was used to select 300 rural farmers in the study area. The results of the analysis of socio-economic characteristics showed that the mean age of the rural farmers who are cultivating cocoyam was 62 years, 78% were male and about 94.0% were married. Forty one percent of farmers attended and completed secondary school education. Cocoyam cultivation was a subsidiary occupation for 93% of the farmers while the mean farming experience was 21 years. Analysis of gross margin and net profit of a unit cocoyam showed that cocoyam production was profitable in the study area. The profitability and efficiency ratios of 0.54 and 1.54, respectively for cocoyam production were obtained. Also, the principal component analysis of cocoyam production as distilled from their respective coefficients revealed that socio-economic characteristics and perception are the major factors that determined cocoyam production in the study area. However, out of all the socio-economic factors, income generated from sales of cocoyam is the most critical factor in determining the production of cocoyam in the study area. It is recommended that governments at all levels should explore the possibility of encouraging the younger generations to be involve in cocoyam cultivation by sensitizing them to the importance of this vital coping strategy crop.

Keywords: cocoyam, principal component analysis, Western Nigeria, profitability

The Cinderella sector? Funding underutilized crop research in South-east Asia

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The need to develop and maximize the benefits derived from agriculture remains an important element of efforts to combat poverty and foster economic growth. In this context, it is increasingly recognized that certain characteristics of smallholder farming systems, such as the cultivation of established crops in combination with underutilized species have a potentially important role to play in delivering a range of policy objectives. However, researchers, policy makers and funders appear to have limited awareness of the strengths of these systems and in particular of the role that underutilized species play in them. The findings of a preliminary survey of agricultural research funding at national and regional levels in South-East Asia suggests that push and pull factors result in agricultural and research policies which continue to favour innovations that support large-scale production of a limited number of species in monocultures. This has resulted in a decline in the return on investment in agricultural research and contributed to the overproduction of certain staples often in sub-optimal conditions. There is a growing need to modify strategies for rural and agricultural development to respond to the changing policy priorities of the region and reduce the dependence of agriculture on a limited number of crops. The largely unfunded expansion of horticulture, the wide range of crop species and diverse farming systems in the region point to the considerable potential for diversification in the region's agriculture. If this is to be achieved, then substantial changes are required in the way agricultural research is conceptualized and implemented. As part of a social innovation approach, modest increases in the scale of investment in underutilized species research in the region could potentially deliver a higher return on investment and enhance the capacity of the region's agriculture to successfully diversify.

Keywords: research, funding, underutilized, policy, innovation



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