

Research Application Summary

RUFORUM promotes research on orphan crop [*Macrotyloma geocarpum* (Harms) Maréchal & Baudet] through support to graduate students

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Abstract

For many African Universities, graduate training research has been perceived to have limited direct development impact. Carnegie Corporation of New York has supported the Regional Universities Forum for Capacity Building in Agriculture, (RUFORUM) to ignite a new approach to graduate research that is hoped will have direct impact on agricultural development. Through a Postdoctoral project, RUFORUM supported four graduate students to work towards the development of market-led Kersting's groundnut [*Macrotyloma geocarpum* (Harms) Maréchal & Baudet] varieties in Benin. Two PhD students and two Master students tackled various topics that included baseline studies to understand cropping system, germplasm characterization, development of resistance to storage bruchids, improving yield, using seed quality production and postharvest handling. The studies are being undertaken through a Postdoctoral Fellowship in Benin to intensify research on the orphan crop *Macrotyloma geocarpum* and aims to establish a breeding program for the crop. In addition to harnessing research of graduate students, this funding scheme enabled enhancing supervisory skills of the Postdoctoral Fellow.

Keywords: high-throughput phenotyping, Kersting's groundnut, orphan crop, Postdoctoral Fellow, RUFORUM

Résumé

Pour des nombreuses universités africaines, la formation supérieure a été perçue comme ayant un impact direct limité sur le développement. La Société Carnegie de New York a soutenu le Forum régional des universités pour le renforcement des capacités en agriculture (RUFORUM) afin de lancer une nouvelle approche de la recherche universitaire dont on espère aura un impact direct sur le développement de l'agriculture. Dans le cadre d'un projet postdoctoral, RUFORUM a soutenu financièrement quatre étudiants de troisième cycle à travailler sur le développement d'une approche axée sur le marché de variétés d'arachide de Kersting [*Macrotyloma geocarpum* (Harms) Maréchal & Baudet] au Bénin. Deux doctorants et deux étudiants en master ont abordé divers sujets qui comprenaient des études de base pour comprendre le système de culture, la caractérisation du germoplasme, le développement de la résistance aux insectes nuisibles de stocks (bruchids), l'amélioration du rendement, la production de semences de qualité et la manipulation post-récolte. Les études sont entreprises dans le cadre d'une bourse postdoctorale au Bénin pour intensifier la recherche sur la culture orpheline *Macrotyloma geocarpum* et vise à établir un programme de

sélection pour la culture. En plus d'exploiter la recherche de ces étudiants de troisième cycle, ce programme a permis d'améliorer les compétences de supervision du boursier postdoctoral

Mots clés : phénotypage à haut débit, arachide de kersting, culture orpheline, boursier postdoctoral, RUFORUM

Introduction

In the GREEN BOOK: A Guide to Effective Graduate Research in African Agriculture, Environment, and Rural Development published in 2004, Patel *et al.* stated that “Combining research and development, working for and with rural people, and making a real difference to the future requires special skills and approaches that are not often required in the industrialized world. Students need to be able to balance their academic requirements with the needs of projects and rural participants. They need the skills and adaptability to work in inter-disciplinary teams and to understand what is required both for their specific discipline and the broader requirements”. Fifteen years later, this reality continues to hold true, raising the urgent need for inclusive research actions in the Sub Saharan Africa.

Africa is home to many orphan crops which are important for food and nutritional security as well as income generation (Hall, 2013). Orphan crops are generally well adapted to harsh environments and have ability to tolerate abiotic stresses (Padulosi, *et al.*, 2009; Tadele and Assefa, 2012; Tadele, 2014). *Macrotyloma geocarpum* is a neglected species (Dansi, *et al.*, 2012) endemic to West Africa. It is presumed to have originated from Central Benin or Northern Togo (Achigan Dako and Vodouhè, 2006). The crop got high nutritional attributes, dry seeds contain about 21.3 % of proteins (Dansi *et al.*, 2012), and many essential amino acids such as arginine, histidine, phenylalanine, lysine and methionine. Moreover, seeds are a good source of minerals such as calcium, iron, zinc, phosphorus, potassium and magnesium (Ajayi and Oyetayo, 2009), and vitamins (Leung *et al.*, 1968). Highly appreciated in Benin, kersting's groundnut is the most expensive grain legume, costing up to USD 7 per kilogram (Agoyi *et al.*, 2019).

Despite the nutritional and economic values of kersting's groundnut, its production is declining. Such observation was made in Ghana by Mensah *et al.* (2016), in Benin by Assogba *et al.* (2015), in Nigeria by Amujoyegbe *et al.* (2007), in Burkina Faso by Tamini (1997) and in Togo by Mergeai (1993). In Benin, within five years, the area under kersting's groundnut production has decreased from about 2696 ha in 2008 to 1379 ha in 2013. Similarly, within 8 years, 65% decrease was observed in the annual production, representing a drop from 2358 tons in 2005 to 820 tons in 2013 (INSAE, 2013). The main reasons for this include the poor returns following high labor investment, which could partially be addressed through availability of improved varieties with quality seeds. However, no improved variety exists for the crop and no breeding program is ongoing.

To bridge this gap, the University of Abomey-Calavi (UAC) has set up a breeding program for the crop. To not deviate from its core mission, which is to train and build capacity of students, the UAC choose to split its breeding activities into research components handled by graduate students. This initiative meets the mandate of RUFORUM who, through a grant received from Canergie Corporation of New York, provide fundings to the Posdoctoral Fellow to support the program.

This paper highlights implementation schemes and shares experiences of the postdoctoral project themed “Towards development of market-led kersting's groundnut [*Macrotyloma geocarpum* (Harms) Maréchal & Baudet] varieties in Benin”

Project focus and implementation

Overall, the aim is to develop improved cultivars of kersting's groundnut [*Macrotyloma geocarpum* (Harms) Maréchal & Baudet] that meet the market demand. Hence, the current project i) assessed genetic diversity within the available germplasm collection, ii) screened for resistance to storage bruchids iii) analyzed gene action for yield, yield components iv) assessed prospects for high throughput phenotyping of yield parameters v) conducted genome-wide association studies that would enable identification of candidate genes for some key yield traits, vi) studied the crop's phenology and reproductive biology that would inform best ways to perform crosses vii) investigated techniques for kersting's groundnut seed production, testing seed health and ability to store and keep germination capacity and vigour, and viii) investigated ways to expand shelf life of grains in storage.

These activities toward the achievement of the overall goal are implemented by graduate students, each handling different components of the overall work. The approach has been chosen for its double benefit, as it enables graduate students to implement their Thesis research while contributing to the achievement of a development goal as a whole.

In technical terms, one PhD research focusing on inheritance of yield and yield components of kersting's groundnut, used the most current genomic tool Diversity Arrays Technology (DArT) to genotype 237 DNA samples isolated from the same number of accessions. The accessions were collected from different countries including Benin, Burkina Faso, Ghana, Nigeria, South Africa and Togo with Benin being the main provider (over 150 accessions). The genotype data generated are useful to assess genetic diversity and conduct genome-wide association studies (GWAS) on specific traits of importance, including yield components. Besides, the students conducted surveys among 305 kersting's groundnut farmers to understand the constraints hindering the crop's production and how much yield is achieved by farmers and the sociomographic factors that influence cropping system of kersting's groundnut. The PhD student deployed Unmanned aerial vehicle (drones) to provide high throughput phenotyping tools using (UAV)-based multispectral imagery. He investigated the phenology of kersting's groundnut at both vegetative and reproductive phases and how flower is initiated, develops and matures. He investigated pollen maturity and germination times and whether this period matches stigmat receptivity. This research enabled the team to understand what would be the right moment to perform emasculation and make crosses.

The second PhD student has surveyed over 300 famers to understand the kersting's groundnut grain storage conditions in rural settings. He collected 80 samples from farmers' granaries which he assessed for seed physiological quality and seed germination and vigour tests in laboratory. Also he conducted lab experiments for seed health analysis (fungi and bacteria infestation) to evaluate the infection frequency and incidence as influenced by the handling technics and the collection location. He also assessed how long can be the shelf life of kersting's groundnut grains using the traditional techniques. He tested seed morphology versus germination characteristics, effect of seed size on viability and vigour, effect of production techniques on seed yield, quality and storability, effect of harvest period and drying methods on seed composition and physiological quality. The student investigated which local storage technics proove the best, how long do the technics keep the grains and how much germination capacity and vigour seeds can keep under such conditions.

One Master student has completed his research Thesis on morphological characterization of kersting's groundnut. He conducted field experiment in Djidja, the most important kersting's groundnut producing area of Benin. The experiment used 81 accessions laid in Alpha lattice design

with three replications, covering about 0.5 ha. He collected data on thirty four (34) morphological descriptors, including 22 quantitative and 12 qualitative traits. He defended brilliantly his Thesis and received the highest distinction.

Another Master student collected grain samples from the main kersting's groundnut markets of Benin, the samples were kept in laboratory for about 80 days to identify invading insect-pests. Insect-pests identification was done in the Insectarium at IITA-Benin. Thereafter, he screened 86 accessions for resistance to bruchids (*callosobruchus maculatus*), the most harmful storage insect pest. This was done using mass rearing of insect in Lab conditions at the University of Abomey-Calavi. Activities in the Lab include eggs and insect counts to compute medium development period (MDP) and Dobbie Susceptibility Index (DSI). These enabled identify accessions with resistance to bruchids. This student has his Thesis ready which is undergoing examination, he will soon be scheduled for defense. In addition to the graduate students, three memories from bachelor students have been developed and brilliantly defended, a fourth memory is underway.

Research outcomes

From the various experiments and surveys that have been carried out or underway, some good results have been achieved. From the UAV experiment, it came out clearly that multispectral imagery has potential to allow estimates of vegetation indices (VIs) yield components at different growth stages of the crop, thus enabling high throughput phenotyping of yield traits in kersting's groundnut. The floral biology and phenology study showed useful information on size, anatomy and development scheme of reproductive organs. The various stages of floral development have been characterized. The optimum moment for emasculating flowers and making crosses is understood.

It came out from surveys that kersting's groundnut cropping system is influence by sociodemographic factors and calendars for cropping activities slightly vary from one production zone to another. Also it was found that constraints to address include the development of improved varieties and sustainable seed system for the crop. The development of proper agronomic practices and steady cropping calendars that allows cultivation in the longer rainy would reduce loss due to difficult harvesting during dry season. Besides, it came out that grain storage for kersting's groundnut bear lots of challenges that farmers would love to be relieved of. An inventory of the storage tools and techniques has been done and assessment of efficiency and ways to improvement of the various tools is underway.

Identification of storage pests of kersting's groundnut revealed bruchids *Callosobruchus maculatus* and its parasitoids *Dinarmus basalis* as the main insect species that populate kersting's groundnut grain in storage. Besides, two accessions were found to show resistance to storage bruchids. TK9-1 from Ghana was highly resistant and Sag1 from Benin was moderately resistant. These accessions are potential parental lines that can be used in breeding programs.

The morphological characterization of 81 accessions exhibited four clusters based on the 34 quantitative and qualitative traits. The most high yielding accession was from Burkina Faso, potential yield as high as five tons per hectare was observed. Some potential lines were found among Benin's lines, exhibiting up to 4.7 tons per hectare. Hence, this study enabled identify potential lines for quick release and parental lines for the breeding program.

Experiments on seed production techniques has shown some preliminary results as to plant spacing, fertilisation regime, harvest periods, weeding periods, planting season, etc. There is need to repeat the experiment for a second season to confirm the observations made in season one.

As for the deliverables, the project has generated two Master Theses, three Memories, Two scientific papers published in peer-reviewed journals, five manuscripts under peer-review and six other manuscripts under active preparation.

Beyond the routine Research implementation and Thesis preparation, during this fellowship, specific emphasis was put on mentoring the PhD students to look for additional funds and attend workshop trainings and short courses for their professional growth. Hence, so far the two PhD students have benefitted from grants from four donors' institutions such as TWAS, IFS, RUFFORD and Global Partners. They both have attended three workshop trainings viz Molecular Biology Training and Open Labware Building Workshop from 1st-5th April at University of Abomey-Calavi in Benin, Integrated Seed Sector Development course from 06 to 24 May 2019 at Wageningen Centre for Development Innovation in Netherlands, and Marker Assisted Breeding training from 1st-30th September 2019 at BecA- ILRI in Nairobi Kenya. Also they participated in international conferences to deliver oral and poster presentations in Nairobi, Kenya, and Montpellier, France.

Insights for the Postdoc Fellow

Walking through this journey is a continuous learning process that is leading to rapid professional growth for the Postdoc Fellow. He had to deal with some conflictual and difficult situations, some of which were: arguments between Fellowship students or between students and workers, contradicting advise/comments from co supervisors, failure to meet deadlines and in some instances students tend to be very slow or show inaptitude to deliver a planned milestone, etc. He was able to deal with such situations drawing from the close mentorship he has received and more importantly, using the tools he has acquired during the Leadership Enhancement Program for Agricultural Research and Development (LEPARD) course that RUFORUM sponsored him to attend in October 2018. Also through this fellowship the Postdoctoral fellow had the opportunity to develop professional networks during gatherings, and through exchange with senior colleagues to seek for lab facilities or outsource lab services from renowned institutions. His supervision skill has been greatly enhanced and he got more visible to the National Agricultural Research System in Benin and other well known research institutes worldwide.

Conclusion

Overall, the fellowship has been a great opportunity that enriches the career development of Fellows. It is a well thought funding scheme that has a double advantage of providing research platform to both graduate students and Postdoc Fellow, but also enables the Fellow to handle students, develop strategies to deals with difficult and conflictual situations and above all enhance his supervision skills. In addition, in the case of Benin, it is a good starting point for a research career, as this offers opportunity to justify the Fellow's ability to manage grants and be a research Principia Investigator (Team Leader). Hence, the Postdoctoral scheme is a boulevard to career development for young researchers. It would be useful to allow more time for the fellowship, so as to enable completion of the PhD Theses, and to enable Fellows to have more time to push to publication most of the papers that are been generated from the research project. Looking ahead, this fellowship will lead to release of some of the promising kersting's groundnut lines that have been identified. It would also provide opportunity for more Master students to get on board, hence more Theses and papers generated.

Acknowledgment

We are grateful to the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) who through Carnegie Cooperation of New York has provided financial and technical supports for the implementation of this project through the first author of this paper. This paper is a contribution to the Fifteenth RUFORUM Annual General Meeting held 2-6 December 2019 in Cape Coast, Ghana.

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