

1. INTRODUCTION

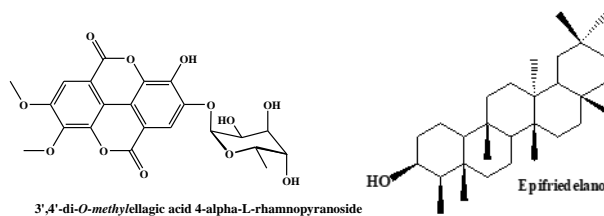
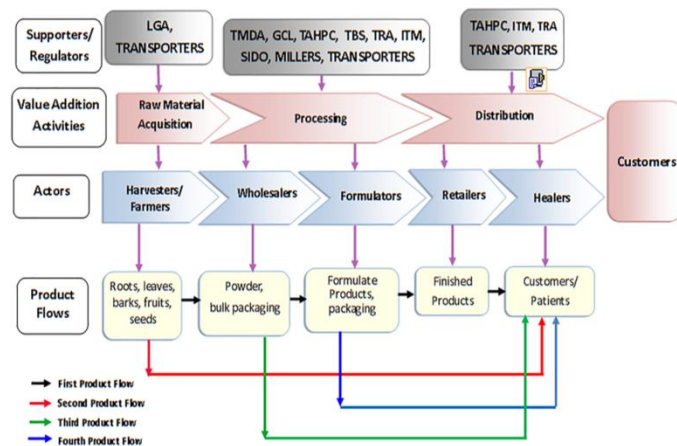
Tanzania is the home of about 31% of the African flora, of which 9% is said to have Green Resource Products (GRPs) potential with pharmacological and economic importance. GRPs specifically medicinal plants (MP) are used as traditional medicine forming a key component for primary health care and livelihoods of more than 50% of the Tanzanians. Despite the contribution of GRPs to the primary health care system, their utilization has been informal and indecent, with low quality, not coordinated hence poor contribution to people's livelihood. This project establishes mechanisms to add value, develop and organize the market and trade of GRPs.

The GRILI project commenced in 2018. It is being carried out in Tanzania and implemented at Sokoine University of Agriculture (SUA) in collaboration with five other research institutions¹. GRILI project has been investigating the contribution of GRPs to people's livelihood, by strengthening the research capacity and generating new knowledge of relevance to the commercialization of the products in Tanzania. The aims were to i) strengthen the institutional research capacities on GRPs value addition through the improvement of technical capabilities and by building human capacity for use of GRPs, ii) identify and characterize antimicrobial active ingredients of GRPs from *Synadenium glaucescens* (SG) and *Commiphora swynnertonii* (CS) as model plants iii) determine the likelihood that resistance may develop towards antimicrobial active ingredients of GRPs from SG and CS, iv) determine the extent and effect of adulteration of GRPs in the Tanzanian market with specific emphasis on GRPs from SG and CS, v) develop a business model for commercialization of GRPs by different actors in the GRP-value and supply chains and, vi) disseminate results to policymakers and end users at national and international level.

To accomplish the project goal, the activities were divided into four research work packages (WP) and followed the holist approach where stakeholders were engaged in all research stages. A reconnaissance survey revealed the value/supply chain of GRPs/MP feeding to the stakeholders' engagement plan. Stakeholders' engagement for data collection, dissemination, and human capacity building was strategically done through training of young scientists, workshops, exhibitions, policy dialogues, field and institutional visits (North-South, South-South, and South-North), joint supervision of students, and joint preparation of scientific publications. Cross-section studies and experimental studies were conducted. The two most promising plant species, SG, and CS, with known antimicrobial properties of crude extracts were selected and used as research models for GRPs. The Njombe, Manyara, Arusha, and Morogoro regions, where these plants are found in plenty and utilized as a source of traditional medicine, formed the focal areas for data and sample collection. Crude extracts, fractions, and pure compounds were tested for antibacterial and antiviral efficacy. Analysis of plant samples was done in Tanzania and Denmark. Institutional capacity building in the south was done to ensure the sustainability and impact of the project.

2. RESULTS

The project results are revealed through the Human and institutional capacity observed within the project period. The GRPs holistic value chain approach was used to strategies stakeholder engagement during the implementation.



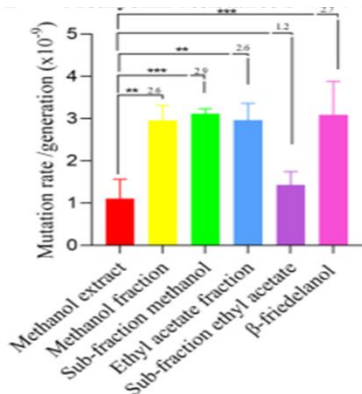
The project has trained 9 young researchers in Tanzania (5 PhD (4 males, 1 female) and 4 MSc. Students 3 females and 1 male in Tanzania. Three Danish students (MSc. 2 females and 1 male) benefited from the project implementation. A total of 36 compounds from model plants were isolated and characterized. The project has published 20 journal articles. The extracts,

fractions, and pure compounds from SG indicated more activity and a wider safety margin, demonstrated the potential to inhibit the growth of Gram-positive bacteria, including Methicillin-Resistant *Staphylococcus aureus*. Methicillin-resistant *Staphylococcus aureus* encodes a *hemB* gene and has the potential to confer resistance to Epifriedelanol an active ingredient in SG. The likelihood and rates of resistance development towards antibacterial compounds and extracts of medicinal plants were generally low. Rate of resistance development was shown to increase with the purification grade of plant extracts as hypothesized in the project application. Two of SG compounds (3',4'-di-O-methylsuccinic acid-4 α , L-rhamnopyranoside, Epifriedelanol) can be used as markers of the activity of the two model plants. They are the standards for the quality

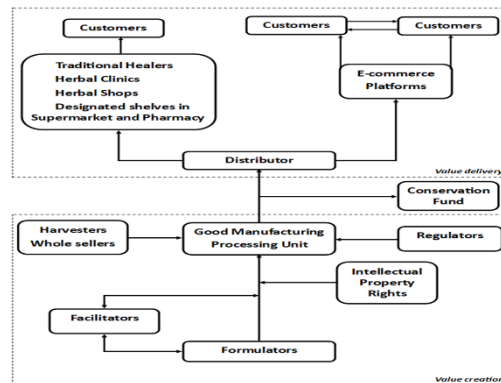
¹ Nelson Mandela African Institute of Science and Technology Tanzania, Institute of Traditional Medicine (ITM-MUHAS), The National Institute for Medical Research (NIMR), Mzumbe University (MU), and the University of Copenhagen (UC)

improvement of GRPs of the plant. Herb-herb and herb-antibiotic interaction studies indicated synergism, additive and antagonistic effects. Synergistic interactions indicate potential to overcome antibiotic resistance problems, while antagonistic effects call for awareness creation among formulators.

The project developed and optimized 8 screening methods for detecting and quantification for antibiotic, antimalarial, anti-pain, corticosteroids, mycotoxins and anti-impotency adulterants in herbal medicines. Methods were used to identify and make estimates of adulteration rates for herbal medicines in Tanzania. Confirmatory experiments using LCMSMS, indicated adulteration at a rate of 0% - 10%, which calls for a strategic surveillance plan by the government to ensure that it does not contribute to the antibiotic resistance threats. These methods contribute to strengthening the regulatory capacity of government bodies in the standardization and quality control of GRPs.



Studies has indicated lack of business skills and support services to traditional practitioners (TP) of HM for the production of finished products. As part of the dissemination of results, 150 TP were trained on GMPs², formalization of GRPs business and efficacy and safety. 30% of them are currently formalizing their products. The results were also disseminated through policy dialogues, exhibitions, field visits, workshops and meetings with stakeholders. As a result of



policy dialogues, the government lowered the price of analysis of GRPs by 50%. Furthermore, the project proposed a business model for GRPs to be able to contribute to people's livelihood. The project has installed state-of-the-art equipment (LC-MS/MS machine) with stable power backup at SUA. This is a replica laboratory of UC. A team of technical professors from UC trained 25 technical staff on the use and troubleshooting. During the period, 3 mini research laboratories were installed. Further, it has furnished a phytochemistry laboratory with a melting point machine, Sonicator, Freeze drier, freezer and two refrigerators. This has strengthened the capacity for research, collaboration and control of GRPs.



The project launched the first National Traditional Medicine Scientific Conference in Tanzania, which was taken over by the Ministry of Health as an ongoing annual event. The GRPs value addition concepts have been incorporated into the new curriculum at SUA.

3. CONCLUSION

As evidenced from the results, interventions following the holistic approach encompassing the GRP value chain brings more impact on the quality and commercialization of the GRPs in Tanzania. The holistic approach used in the implementation of this project has enabled The presence of medicinal chemical compounds in SG and CS, which can be used for the development of antimicrobial drugs, is an opportunity for interested actors to invest in producing promising medicines from the two medicinal plants. Additionally, identification and quantification of conventional drugs adulterations in HM can be done through simple methods developed by GRILI project. However, the sustainable production and use of GRPS need the TP to have the right business skills and support service, up-scaled production of finished products. The required capacity building and support services can be easily provided if the TP are mobilized in groups or business partnerships using the business model developed by the GRIL project.

4. RECOMMENDATIONS

The Government should set a budget for the upscaled investigation following the value chain approach to provide guidelines on the required combination, use the marker compounds for the standardization and quality control of herbal drugs. This should consider capacity building from the North and within the stakeholders in GRPs value chain. Application by responsible authorities in Tanzania, of those screening methods developed in monitoring adulterations is necessary for ensuring the quality and safety of GRPs in Tanzania. This needs to go together with efforts of sustaining training of practitioners of HM on medical ethics and implications of drug adulterations for curbing drug malpractices. The Ministry of Industry and Trade considers setting a budget to incorporate GRP trade for the formal income of Tanzanians.

<https://doi.org/10.21010/Ajid.v16i2S.2;> <https://doi.org/10.1007/s42250-022-00457-7;> ; <https://doi.org/10.7454/psr.v9i2.1262;>
<https://doi.org/10.31254/phyto.2022.11504;> e10426. <https://doi.org/10.1016/j.heliyon.2022.e10426;> <https://doi.org/10.31254/phyto.2022.11506;> ;
<https://doi.org/10.1007/s10600-023-04083-8;> 0.22127/RJP.2023.370231.2009; <https://doi.org/10.3389/fitd.2022.1104543>
<https://doi.org/10.1039/d1ay01966j;> <https://doi.org/10.1007/s44211-022-00255-8;> <https://doi.org/10.3390/separations10010023>

² Good Manufacturing Practices