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01 *Myrothamnus flabellifolius* (Resurrection plant) endophytes enhance okra growth and nutraceutical quality

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Abstract

Drought-tolerant plants host endophytic bacteria with untapped potential as microbial biostimulants for sustainable agriculture. The bacterial strains used in this study were previously isolated and characterised from *M. flabellifolius*, a Namibian resurrection plant, and were evaluated for their ability to enhance crop establishment and functional food quality in okra (*Abelmoschus esculentus*). Three bacterial strains, *Kosakonia cowanii* (KC), *Bacillus licheniformis* (BL), and *Cupriavidus metallidurans* (CM), exhibited multiple plant growth-promoting traits, including nitrogen fixation, ACC deaminase activity, phosphate solubilisation, and production of ammonium, siderophores, and indole-3-acetic acid. Okra seeds were inoculated with individual strains or bacterial consortia and cultivated hydroponically using the Kratky method under a randomised complete block design.

The KC-BL consortium significantly improved germination from 51.4% to 70.1% ($p < 0.001$) and seedling vigour index from 513.01 to 846.46 ($p < 0.001$) compared with the uninoculated control. Beyond growth promotion, microbial treatments influenced the nutraceutical properties of okra pods. Methanolic extracts from KC-BL-treated plants showed the highest α -amylase inhibition (92% at 2500 $\mu\text{g/mL}$), with IC_{50} values comparable to acarbose ($<19.53 \mu\text{g/mL}$). Aqueous extracts from CM-treated plants demonstrated exceptionally strong α -glucosidase inhibition ($\text{IC}_{50} = 0.00015 \mu\text{g/mL}$), suggesting enhanced antidiabetic potential. Antimicrobial activity was observed against *Mycobacterium avium* (13.00 mm inhibition zone), *Salmonella typhi*, and *Candida albicans*, with methanolic extracts exhibiting bactericidal and fungicidal effects. Methanol outperformed acetone and distilled water in extracting polar bioactive compounds. These findings demonstrate that resurrection-plant-derived PGPB, particularly the KC-BL consortium, can simultaneously enhance early crop establishment and enrich nutraceutical quality. Integrating such microbial resources into water-efficient hydroponic systems offers a promising strategy for resilient, nutritionally valuable food production in semi-arid environments.

02 Evaluation of *Bradyrhizobium* bioinoculant on selected legumes and characterisation of *Faidherbia albida* soil bacteria

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Abstract

Environmental factors including infertile soils and climate change as well as high cost of fertilisers are major threat to sustainable food production in dry regions. Improvement of climate adapted plant–microbe methods through biological nitrogen fixations offers resources efficient and transgene-free pathway to strengthen food security. This study evaluated the effect of a *Bradyrhizobium* bioinoculant and Plant Growth promoting Rhizobacteria (PGPR) on the growth and nodulation of selected drought-tolerant legumes under greenhouse and field conditions and characterised culturable bacteria associated with *Faidherbia albida* soils.

Namibia is facing serious environmental issues, the result has been widespread soil erosion, declining soil fertility and a noticeable reduction in natural vegetation recovery. The application of bioinoculants has been shown to enhance crop growth and yield while reducing dependence on chemical inputs, therefore, the objectives of this study are as follows: (1) to evaluate the effect of *Bradyrhizobium* bioinoculant on the germination and growth of *Tylosema esculentum* under pot conditions; (2) to evaluate the effects of microbial bioinoculant treatments on the growth, nodulation and yield-related performance of Nakare and Silwana varieties of *Vigna unguiculata* under traditional and conservation agricultural practices and (3) to isolate and identify culturable bacteria from bulk soil associated with *F. albida* Research

Greenhouse and field experiments were conducted using *Bradyrhizobium* inoculation, PGPR inoculation, fertiliser and control treatments. Plant growth, nodulation and biomass parameters were measured. Culturable Soil bacteria associated with *F. albida* soils were isolated and identified using the Vitek Compact 2 system.

Part 1: To determine the effectiveness of *Bradyrhizobium* (1-7) bioinoculant on *T. esculentum*, one way analysis of variance (ANOVA) test was used to discover whether significance differences existed between treatments. Significance level was $p \leq 0.05$ and all analysis was done using R version 4.5.1. *Bradyrhizobium* bioinoculant significantly increased plant height with P value of 0.000245. *Bradyrhizobium* bioinoculant treatment recorded the highest germination rate (80%) and tallest plants, while biomass, width and leaf production were not significant. Chlorophyll absorbance differed significantly at AU 663 ($p = 0.00006$), AU 646 ($p = 0.00002$), and AU 652 ($p = 0.032$), with the control showing the highest values. Bioinoculant treatment had the best performance with respect to plant height, followed by fertiliser treatment while the control treatment had the lowest height. The results showed that *Bradyrhizobium* bioinoculant promotes early plant growth but does not significantly enhance chlorophyll content under the study conditions

Part 2: Silwana cultivar, untreated plots had the highest germination rate of 95.5% followed by inoculant treatment with 87.25% then control treatment without mulch with germination rate of 82%. Plots with urea treatment had the lowest germination rate of 58.25% while for Nakare cultivar untreated plots had high germination rate of 82% and Inoculant with mulch 81% germinated. Sticking agents and urea performed worst with Wheat flour having 23.75% of germination, Gum arabic having 31.25% germination rate and Urea with 34.75% germination rate. Silwana: inoculant and inoculant+mulch plots were the fastest to reach 50% flowering stage. The same pattern was also observed in 50% podding. Nakare did not reach 50% flowering and podding. Silwana: inoculant treatment had the highest number of nodules 17.7 nodules while 14.574

nodules were observed in urea treatment and 14.05 were from control treatment. Control + mulch treatment had few nodules 2.55 nodules. Nakare: Brady + PGPR treatment had the highest average number of nodules of 25.06. plot with few nodules was inoculant – mulch (5.6). Silwana: Traditional agricultural field (TA) had more germination rate of 80.7% compared to conservation agricultural field (CA) that had germination rate of 65.32%. TA had more average number of nodules (15.77) per plant than CA (6.49). CA only outperformed TA in plant height with tallest plant of 51.73 cm vs 34.4 cm plant height in TA. Nakare: TA had significantly higher seed weight of 31.71 g vs CA with 26.64 g while CA yielded taller plants 83.27 vs 56.31 cm in TA.

Part 3: A total of 42 bacterial isolates were recovered from *Faidherbia albida*-associated soil and identified using the VITEK 2 Compact system. The isolates represented diverse Gram-positive and Gram-negative taxa including *Staphylococcus*, *Sphingomonas*, *Enterobacter*, *Pantoea* and *Pseudomonas*, suggesting that *F. albida* soils harbour diverse bacterial communities with potential agricultural importance. *Staphylococcus* spp. were the most frequently identified bacteria (42.9%), followed by *Sphingomonas paucimobilis* (19.0%) and *Enterobacter ludwigii* (9.5%). Other identified taxa included *Enterobacter* spp., *Pantoea* spp., *Enterococcus columbae*, *Pseudomonas putida*, *Serratia grimesii*, and *Klebsiella oxytoca*.

In conclusion, *Bradyrhizobium* (1-7) bioinoculant was very effective on *T. esculentum*, increasing germination rate and having taller plants compared to other plants. Inoculant may have stimulated early shoot growth. However, the absence of significant differences in biomass and leaf production indicates that the treatments did not greatly enhance overall plant productivity within the study duration. TA consistently influenced nodulation and seed yield while CA influenced vegetative growth such as height and shoots. Legumes return fixed nitrogen to the soil through dead organic matters increasing nitrogen in the soil for other crops thus reducing the need for chemical fertilisers. This is the agronomic bridge between trial and long-term soil fertility improvement. More nodules mean more nitrogen available to non-legumes crops.

03 Bacterial community and potential food safety risks in irrigation water sources used for fresh produce in Namibia

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Abstract

Namibia, an arid nation, relies on irrigation to cultivate fresh produce. However, irrigation water can be a source of waterborne and foodborne pathogens, posing public health risks when introduced into fresh produce systems. The microbial quality of irrigation water in Namibian farms and green schemes has not been investigated and remains poorly understood. Irrigation water and sediment samples were collected from individually owned small-holder farms and government-operated green schemes across Namibia. Total genomic DNA was isolated, libraries prepared, and the full-length of bacterial 16S rRNA gene sequenced using the PacBio Revio Hi-Fi platform and the HiFi-16S workflow for high-resolution microbial profiling. Analysis revealed that Pseudomonadota was the predominant phylum, comprising 54% of all samples and reaching 93% in groundwater from Grootfontein. Alphaproteobacteria and Gammaproteobacteria were prevalent in both groundwater and surface water, with relative abundances of 37% and 63%, respectively. Notably, Gammaproteobacteria constituted 82% of the microbial community in groundwater from Tsumeb. Sediments from Ndonga Linena and Shitemo green schemes were enriched with Bacillota, Actinomycetota, and related Proteobacteria phyla. The detection of *Escherichia coli* and *Klebsiella* in water samples from Tsumeb, Grootfontein and Otavi indicated the presence of enteric and potentially waterborne and foodborne pathogenic organisms. Additionally, the identification of *Candidatus eremiobacterota* suggested a diverse environmental microbiome. These findings indicate that irrigation water can serve as a conduit for foodborne pathogens and underscore the need to understand microbial dynamics in irrigation systems to enhance water management practices, ensure safe fresh produce production, and support human, plant, and environmental health, aligning with sustainable development goals.

04 Performance of Bambara Groundnut Varieties under Single and Composite *Bradyrhizobium* Inoculation in Communal Lands of Kavango East, Namibia

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Abstract

Bambara groundnut (*Vigna subterranea* (L.) Verdc) is a drought-tolerant legume with substantial nutritional and food security value across Sub-Saharan Africa, particularly within Namibia's Northern Communal Lands. [Majola et al., 2021; Kunene et al., 2022]. Despite its significance, production and yield among subsistence farmers in Kavango East region remain low. Due to the prevalence of marginal soils, predominantly classified as Arenosols, characterized by poor nutrition status, low water-holding capacity, compounded by variable climatic conditions [Luchen et al., 2018; Hartemink & Huting, 2008]. Recent advances in plant-microbe interaction underscore the potential of nodule associated rhizobacterial inoculants, which not only enhance biological nitrogen fixation but also offer a range of plant growth promoting functions. An experiment was conducted at Mashare Research Station, between December 2025 - May 2026, using a randomized complete block design (RCBD) with five replications. The total experimental area measured 953.125 m² (62.5 m × 15.25 m), comprising 70 subplots (14 per replicate). Each BGN variety was subjected to three treatments: uninoculated negative control, an uninoculated positive control (+ urea), and an inoculant treatment. Each variety was inoculated with a compatible single or composite *Bradyrhizobium* strain based on prior studies (Fwanyanga, 2023; Sarkar et al., 2023), except for the novel Black variety, which was evaluated against all single and composite inoculants individually. Pre-planting and post-harvest soil analyses were conducted to assess changes in soil physicochemical properties. Field data has been collected and analysis is under way.

05 Soil-extracted microbes for biofertilizer

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Abstract

Southern Africa faces significant food and nutrition insecurity due to limited access to fertile land, inappropriate farming practices, high fertilizer costs, and climate change. While inorganic fertilizers help increase productivity, their use has been proven to have negative effects on the environment e.g., greenhouse gas emissions, acidification, nitrate accumulation, and loss of soil biodiversity. Some microbes possess traits (growth-promoting factors) that can enhance nutrient availability and water uptake in soil, produce plant growth hormones, and protect plants from pathogens. The aim of this project is to develop a climate-smart, microbial-based biofertilizer derived from indigenous soil microorganisms to improve soil fertility, crop yield, and climate resilience.

06 Isolation and Characterization of Plant-Growth Promoting Rhizosphere Bacteria Associated with Marama Bean (*Tylosema esculentum*) and Bambara Groundnut (*Vigna subterranea*) in Namibia

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Abstract

Background: Plant-associated rhizosphere bacteria contribute to nutrient cycling and plant-microbe interactions. Marama bean (*Tylosema esculentum*) and bambara groundnut (*Vigna subterranea*) are indigenous African legumes adapted to challenging environmental conditions. However, the diversity and functional characteristics of culturable rhizosphere bacteria associated with these legumes in Namibia remain poorly understood. This study aimed to isolate, identify and characterize plant growth-promoting rhizobacteria associated with both legumes.

Methods: Sandy soil collected from Mashare, Namibia, was used to cultivate both legumes under controlled pot conditions. Rhizosphere bacteria were isolated at the two-leaf developmental stage and identified using 16S rRNA gene sequencing. A total of 45 bacterial isolates were recovered, comprising 23 from bambara groundnut and 22 from marama bean. Isolates were screened for phosphate solubilization, siderophore production, indole-3-acetic acid (IAA) production, hydrogen cyanide production and amplification of the nitrogen fixation-associated *nifH* gene.

Results: The isolates were predominantly affiliated with the phyla Firmicutes and Proteobacteria, with *Bacillus* and *Peribacillus* among the most frequently identified genera. Phosphate solubilization was detected in 91% of bambara groundnut isolates and 55% of marama bean isolates, while siderophore production was observed in 57% and 91%, respectively. The *nifH* gene was amplified in 70% of bambara groundnut isolates and 73% of marama bean isolates. Maximum IAA concentrations were 9.95 µg/mL and 7.87 µg/mL among bambara groundnut and marama bean isolates, respectively.

Conclusion: The findings demonstrate taxonomic and functional diversity among culturable rhizosphere bacteria associated with marama bean and bambara groundnut. Differences in the distribution of plant growth-promoting traits between the two isolate collections provide insights into the functional characteristics of bacteria associated with these indigenous legumes. The study provides baseline information for further investigations into rhizosphere microbial ecology and plant-microbe interactions in Namibian soils.

07 Effect of Bio-Inoculants on Cowpea Performance Under Different Tillage Systems in Kavango East, Namibia

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Abstract

Climate change in conjunction with poor soils, has resulted in a decrease in the yield of most crops planted within the Kavango East Region. Arenosols, sandy, porous soils that are infamous for retaining very little moisture and nutrients, predominate in the area. These combined variables adversely affect most smallholder farmers because they lack the financial means to improve their soils with chemical fertilizers. However, rhizobia, a bacterium found in soil, can help boost plant development and productivity. This study aimed to ascertain how two, *Vigna unguiculata* (cowpea) varieties respond to an introduced bio-inoculant strain 1-7 and whether growing them in a natural environment resulted in increased production and growth, to compare the biomass of the shoots, grains, and roots of the cowpea varieties and the crop yield performance between the conservation agriculture (CA) and traditional agricultural (TA) field. The two cowpea varieties named, Silwana (Si) and Nakare (Na) were cultivated in field experiments at the Mashare Agricultural Development Centre (MADI), in the Kavango East Region of Namibia. The experimental field was subdivided into the TA and CA field. The cowpea varieties were grown in three replicates and subjected to three treatments: one using chemical fertilizer, one using a bio-inoculant of *Bradyrhizobium* strain 1-7, and a third serving as a control. At 128 days after seeding, the cultivars were harvested, and various yield parameters were evaluated. Compared with the fertilizer treatments and the untreated control, cowpeas receiving bio-inoculant applications recorded superior yields. For the Na treatment, shoot, grain and root yields reached 2330.28, 3758.64 and 406.14 kg ha⁻¹, respectively, while the Si treatment produced 2553.87 kg ha⁻¹ of shoot biomass, 2564.07 kg ha⁻¹ of grain and 427.14 kg ha⁻¹ of root biomass. Field management practices also influenced productivity. The CA field demonstrated greater overall performance than the TA field. Shoot biomass in the CA field measured 1589.27 kg ha⁻¹ (Na) and 1942.07 kg ha⁻¹ (Si), compared with 741.01 and 611.80 kg ha⁻¹ under TA management. Grain yield followed a similar trend, with CA recording 1978.80 kg ha⁻¹ (Na) and 1915.94 kg ha⁻¹ (Si), exceeding the corresponding TA values of 1779.84 and 648.13 kg ha⁻¹. In contrast, root biomass was slightly lower under CA (190.55 kg ha⁻¹ for Na and 221.58 kg ha⁻¹ for Si) than under TA (215.59 and 205.56 kg ha⁻¹, respectively). Overall, bioinoculant application improved crop productivity, suggesting a cost-effective and environmentally sustainable alternative to synthetic fertilizers for smallholder farming systems.

08 Mapping the Evidence on Soil Biological Responses to Conservation Agriculture and Microbial Inoculants for Cowpea (*Vigna unguiculata* (L.) Walp.) Productivity in Semi-Arid Sub-Saharan Africa

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Abstract

Conservation agriculture (CA) and microbial inoculants are increasingly promoted as climate-smart strategies for restoring soil health and improving legume productivity. However, evidence on their combined effects on soil biological indicators and cowpea (*Vigna unguiculata* (L.) Walp.) performance in semi-arid sub-Saharan Africa (SSA) remains limited. This scoping review mapped and synthesised evidence on soil biological responses to CA practices, microbial inoculants and their combined application in legume-based systems, with particular emphasis on implications for cowpea productivity in semi-arid SSA. Literature searches were conducted in Google Scholar, Scopus and PubMed. The review identified a scarcity of studies assessing CA and microbial inoculants together, as most studies evaluated the interventions separately. CA was more consistently associated with improvements in microbial biomass, enzyme activity, microbial community composition, arbuscular mycorrhizal fungi colonisation and soil fauna, particularly when the core CA principles were implemented together and maintained over time. However, cowpea yield responses to CA were mixed, especially during the transition period. Microbial inoculants, particularly rhizobial and *Bradyrhizobium* strains, more frequently improved nodulation, nodule biomass, biological nitrogen fixation (BNF), plant biomass and grain yield. Their effectiveness varied according to strain competitiveness, cowpea genotype, phosphorus availability, soil properties, water supply and indigenous microbial communities. Most inoculation studies were short- or medium-term and focused on nodulation and crop productivity, while fewer assessed broader soil biological processes. These findings highlight the need for long-term factorial field studies that evaluate CA and microbial inoculants together using standardised soil biological and agronomic indicators.

09 Demanding Resilience: Plant Breeding for Semi-Arid Crop for Sustainable Food and Feed Systems in Namibia

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Abstract

Introduction: Severe droughts, high temperatures, and poor soils are major constraints to Namibia's food and feed production. Demand-led breeding and genetic diversification are important for building climate-resilient agricultural systems.

Methodology: Our integrated demand-led and speed breeding, combined with biotechnology tools, aims to improve the production of major staples (pearl millet, maize, sorghum, cowpea and Bambara groundnut). Modern breeding involving landraces, wild species domestication and mutation breeding with marker-assisted selection are being deployed to enhance genetic diversity and accelerate breeding cycles. Additionally, underutilized wild species and introduced semi-arid legumes (guar, moth bean, horse gram) are candidate crops for drought-prone agro-ecologies for enhancing yield, adaptation, forage quality, and nutritional value.

Results: Demand-led breeding with Marker-assisted selection can enhance the identification of high-yielding, drought-tolerant, pest and disease resistant and farmer-preferred varieties of staple crops. Domestication and introduced legume trials demonstrated high adaptation, soil nitrogen-fixation, and superior feed potential to mitigate dry-season fodder deficits.

Conclusion: Combining biotechnology, mutation breeding, and species introduction strengthens NUST's crop improvement infrastructure, offering climate-smart food and feed solutions for Namibia's arid environments.

Keywords: Biotechnology; Climate Resilience; Crop Domestication; Demand-Led Breeding; Food and Feed Security