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Bambara groundnuts [*Vigna subterranea* (L.)Verdc] Production Systems in Kavango East Region, Northern Namibia

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ABSTRACT

Background: The productivity of Bambara groundnut [*Vigna subterranea* (L.) Verdc] is gradually decreasing in subsistence farming systems due to various factors, including climate-related issues, socioeconomic limitations and farming practices. This study aimed to identify the reasons for this decrease by examining factors like farming methods, seed color preferences, input quantities and production constraints.

Methods: A participatory rural appraisal study was conducted in the Mukwe and Ndiyona constituencies. Four villages per constituency were selected for the study. A structured questionnaire was employed to collect data on demographics, Bambara groundnut farming practices (including farm size, yield, uses and seed preferences), farming inputs and production constraints.

Result: The study found that most farmers (77.8%) allocated less than one hectare of land annually for Bambara groundnut cultivation. Around 66.7% of farmers reported low yields, typically between 1 and 100 kg per season. Most farmers (85.7%) grew Bambara groundnuts primarily for household consumption, with only 14.3% focusing on income generation. Cream-seeded Bambara groundnuts were the preferred choice among farmers due to their early maturation, high yield potential and ease of preparation. The main production challenges identified in the region included field pests, low yields, lack of improved varieties, expensive labor and high seed costs. To address these issues, the study recommended breeding for improved varieties and using inoculants to increase crop output. These approaches aim to boost yields and provide nitrogen enrichment for subsequent crops.

Key words: Bambara groundnut, Soil fertility, Subsistence farming, Yield.

INTRODUCTION

The global population is increasing and there is a need to focus on increasing agricultural production (Aviara *et al.*, 2013; Khan *et al.*, 2021). The Bambara groundnut [*Vigna subterranea* (L) Verdc.], a resilient and nutritious crop that thrived in Africa before the introduction of the peanut (*Arachis hypogea*), is gaining attention (Temegne *et al.*, 2018; Osundare *et al.*, 2023).

Luchen *et al.* (2018) claim that most soils in northern Namibia have poor nutrition and water retention. Despite the low potential of the poor soils to produce crops, subsistence farming remains the primary source of livelihood and food security for the local population. The yield level on farms currently needs to be determined. It is anticipated to be substantially lower, requiring actions to investigate strategies for enhanced Bambara groundnut production and improved soil fertility (Grönemeyer and Reinhold-Hurek, 2018).

Understanding Bambara groundnut farming systems, variety preferences, choice and quantities of farming inputs and production constraints is crucial for advancing production technology in agriculture (Horn *et al.*, 2015). This study aimed to assess the seed preferences, input selection and quantities and production constraints among Bambara groundnut farmers in the Kavango East Region of Namibia. The choice of this region for the study was driven by the belief that it can potentially be a significant agricultural contributor, “Breadbasket,” to Namibia if local farms become more productive (Luchen *et al.*, 2018). Therefore, this study focuses on Bambara groundnut farming in the Kavango East Region.

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MATERIALS AND METHODS

This study was conducted at the University of Namibia, among two Kavango East Region constituencies, Ndiyona

and Mukwe, in 2021-08 to 2022-12. A participatory rural appraisal approach was adopted when farmers were off-season preparing for the new cultivation period. These constituencies were chosen due to their reputation for crop production, including Bambara groundnuts. Kavango East is located northeast of Namibia, with an average annual rainfall of 450-600 mm and average temperatures of 23-39°C (Valombola *et al*., 2021).

A systematic sampling method was employed to identify Bambara groundnut producers in the region. Data was collected from four villages in the Ndiyona constituency (Dumushi, Kakekete, Dosa, Rucara and Shikoro) and four villages in the Mukwe constituency (Mbapuka, Tjova, Katenture and Shamangorwa). Eighty households were included in the sampling, with ten Bambara farming households sampled in each village. However, only seventy households could participate in the interviews due to some farmers′ unavailability.

A structured questionnaire was used to collect demographic data, Bambara groundnut farming practices (such as farm size, planted area, average yield per hectare per year, primary uses and seed preferences) and information on farming inputs and production challenges. Interviews were conducted in local languages (Rugciriku and Thimbukushu) and later translated into English.

The accrued data was analyzed using descriptive statistics, including cross-tabulation, frequencies and graphical representations through the Statistical Package for Social Sciences (SPSS) version 23 program. Pearson's Chi-squared test was also employed to assess associations and dependencies among variables without parametric data.

RESULTS AND DISCUSSION

Demographic data of participants

The study revealed no statistically significant correlation between the farmers' age and the constituency they belonged to, as indicated by a cross-tabulation analysis (χ^2=4.243; P<0.374). In terms of age distribution among the interviewed farmers, 31.7% were aged 60 years or older, 30.2% fell in the 50-59 age range, 22.2% were in the 40-49 age range, 11.1% were in the 30-39 age range and 4.8% were in the 20-29 age range. While an association was detected among genders, no significant association was identified with household size (Table 1).

The study′s results show that most participants were between 40 and 60 years old, which aligns with Valombola *et al*. (2021) study. This age range may be due to younger individuals migrating to urban areas for employment opportunities, leaving older people to continue farming in rural regions. It is argued that one of the leading causes of rural young individuals′ migration to urban areas is their negative attitudes toward agricultural pursuits. However, Horn *et al*. (2015) suggested that youth migration to cities could be reduced if they are motivated to engage in agriculture, where they can produce for income generation.

The study also identified a gender disparity, with fewer men engaging in Bambara groundnut cultivation. This result concurred with Karunaratne *et al*. (2015) and Valombola *et al*. (2021) findings. This disparity may be due to men prioritizing alternative income-generating activities seen as more profitable or prestigious than Bambara groundnut farming. Traditional gender roles in some societies also assign specific agricultural tasks based on gender, with Bambara groundnut cultivation traditionally associated with women. Addressing this gender gap may require interventions that challenge gender stereotypes, promote gender equality, provide training and resources to enhance men's agricultural skills and raise awareness about the economic and nutritional benefits of Bambara groundnut cultivation. Involving men in sustainable agriculture is essential for inclusive agricultural development and food security.

Bambara groundnut farming systems

The Bambara groundnut farming systems in the two constituencies of the Kavango East Region are summarized in Table 2. Significant differences were observed in farm sizes between the two constituencies (P = 0.016), with 65.1% of farmers having farm sizes between 2 and 5 hectares, 11.1% with farm sizes larger than 5 hectares and 23.8% with 1 hectare or less. However, no significant differences were found in the area allocated for Bambara groundnut cultivation (P<0.576). Most farmers (77.8%) reported allocating less than 1 hectare for Bambara groundnut cultivation, while 22.2% allocated more than 1 hectare. This study highlighted that farmers in the Kavango region often

Table 1: Socio-demographics of Bambara groundnut farmers that were interviewed.

Variables		% of farmers	df	χ^2	*p*-value
Gender	Female	87.3	1	10.279	0.001
	Male	12.7			
Age (in years)	20-29	4.8			
	30-39	11.1			
	40-49	22.2	4	4.243	0.374
	50-59	30.2			
	≥60	31.7			
Household size	≤10	46.0			
	11-20	46.0	2	0.639	0.727
	≥21	7.9			

Table 2: Bambara groundnut farming systems in the two constituencies in the Kavango East region in Namibia.

Variables		% of farmers	df	χ^2	*p*-value
Size of the farm	≤1 ha	23.8	2	8.304	0.016
	2-5 ha	65.1			
	≥5 ha	11.1			
Area planted with BGN	≤1 ha	77.8	1	0.313	0.576
	≥1 ha	22.2			
	≤50 kg	42.9			
Average yield per year	50-100 kg	23.8	2	10.171	0.006
	≥100 Kg	33.3			
Main uses	Home consumption	85.7	1	2.922	0.087
	Income generation	14.3			
Seed color preference	Black	20.6			
	Brown	6.3			
	Red	17.5	4	18.898	0.001
	Cream	54			
	Chocolate	1.6			
Reasons for seed preference	Early maturing	27			
	Easy to cook	17.5			
	High yielder	22.2	4	27.592	0.000
	Size (big)	17.5			
	other	15.9			

allocate their cropping areas based on their preferred or most valuable crops. In the case of Bambara groundnut, smaller areas were allocated, indicating that many farmers in the two constituencies prioritize other crops over Bambara groundnut, as larger farming areas are typically dedicated to the most valuable crops (Horn *et al*., 2015). Fleissner (2006) found that in the Kavango region, Bambara groundnut was the sixth most important crop, with 67% of farmers involved in its cultivation. Similarly, Bambara groundnut received lower priority in Zimbabwe when allocating land among villages (Hillocks *et al*., 2012).

There were also significant differences in annual average yields of Bambara groundnut ($P<0.006$). Approximately 42.9% of farmers harvested less than 50 kg annually, 33.3% harvested 100 kg or more and 23.8% harvested between 50 and 100 kg. The local farmers in Namibia, especially in the Kavango region, have been cited in Grönemeyer *et al.* (2016) as having to deal with low yields and declining soil fertility, which could harm them. The decline in soil fertility could also be attributed to the underprivileged utilization of fertilizer in both constituencies where the study took place. Only 8.7% of farmers in Ndiyona Constituency reported that they use fertilizers in their crop fields while 100% of the farmers in the Mukwe Constituency reported that they do not use any fertilizers in their fields (Table 3). Therefore, measures to restore soil fertility and production in previously degraded fields are essential to ensure food security and increased yield. These measures can include the application of green and farmyard manures, promoting root nodulation for nitrogen fixation through rhizobial inoculants, composting and utilizing crop residues, as well as crop management options such as natural fallow. Other essential cropping practices that could reverse the deterioration in soil health include intercropping, relay cropping, cover crops, crop rotations and dual-purpose legumes. Among these techniques, legumes are widely recognized as soil fertility builders and restorers, owing to their relationship with symbiotic nitrogen fixation (Musa *et al*., 2016).

Consequently, microbial inoculants have been used to improve agricultural production, soil health and plant health (Das *et al*., 2018; Saad *et al*., 2020). Many studies have demonstrated that microbial inoculants can significantly boost legume nodulation, nitrogen fixation and grain yield, particularly among subsistence farmers (Thilakarathna *et al*., 2019; Ibny *et al*., 2019; Allito *et al*., 2021; Gedamu *et al*., 2021). For instance, a study in the Kavango East Region by Luchen *et al.* (2018) demonstrated that cowpeas treated with bio-inoculants yielded higher grain yield than negative control and fertilizer treatments. This shows that bio-inoculants may offer local subsistence farmers a cost-effective and eco-friendly means to enhance Bambara groundnut and other crop yields.

Regarding the purpose of cultivation, 85.7% of farmers in the Kavango East Region grew Bambara groundnut for home consumption, while 14.3% grew it for income generation. This suggests that most farmers primarily cultivate Bambara groundnuts for consumption rather than sale. However, some farmers reported selling their produce or seeds informally at open marketplaces during planting seasons. This study revealed that Bambara groundnut is underutilized and lacks attention in Namibia, unlike other countries where it is used for various purposes (Temegne *et al*., 2018).

Table 3: Reasons for not using fertilizer in the two constituencies in the Kavango East Region.

Constituency	Reason for farmers not using fertilizer				
P-value	% of farmers who do not need fertilizer	% of farmers who do not use fertilizer due to availability		df	χ^2
Mukwe	57.5	42.5	1	6.86	0.032
Ndiyona	73.9	17.4			

Table 4: Traditional dishes prepared from Bambara groundnut in the two constituencies in Kavango East Region.

Traditional dishes from Bambara groundnut in Kavango	Preparation
Stiff porridge "mugombakapindi"	1. Boiled dry seeds with mahangu flour
Relish/soup	2. Fresh seeds/ dry roasted seeds, boiled into soup
Snacks "shikuvira"	3. Roasted dry seed flour mixed with peanut flour
Boiled seeds	4. Boiled seeds, when fresh or dry, mixed with corn
Instant porridge "rutura"	5. Roasted dry seed flour with warm water

Farmers in both constituencies considered the preferred seed color when choosing Bambara groundnut varieties and there was a significant difference in seed color preference between the two constituencies (χ^2=18.898; P<0.001). In Ndiyona, the majority favored black-seeded Bambara groundnuts, followed by red-seeded varieties, while in Mukwe, brown-colored seeds were unpopular, with most farmers preferring cream-colored ones. Overall, cream-colored seeds were the most popular (54%), followed by black (20.6%) and chocolate (1.6%). These preferences were similar to those found by Valombola *et al*. (2021). However, Hillocks *et al.* (2012) reported that red-seeded varieties were more dominant in Zimbabwe than cream-colored ones and commanded a higher market value. Moreover, farmers selected their preferred seed colors based on various characteristics, including early maturation, easy cooking, high yield potential, size (largeness) and other factors such as resistance to wilting, particularly for red-colored Bambara groundnuts. The Chi-square test showed a highly significant association (χ^2= 27.592; P≤0.000) between seed selection criteria in the two constituencies. According to Odongo *et al*. (2023), Bambara phenotypes that are strongly associated with grain yield give breeders alternatives to characteristics selection in Bambara breeding. Farmers explained that specific Bambara groundnut colors, like the red ones, can be bitter, challenging to cook, or hard to crush for relish preparation. According to Mubaiwa *et al.* (2017) and Khan *et al.* (2021), the hard-to-cook phenomenon is the main issue restricting the use of Bambara groundnut.

Traditional dishes prepared from Bambara groundnut

Bambara groundnut is consumed in various ways at various stages of maturity in the two constituencies in the Kavango East Region (Table 4). After boiling for nearly an hour, newly collected pods are consumed as a snack. Dry Bambara groundnuts are versatile and used in various culinary preparations in Namibia. They can be mashed to create soups or relishes and roasted for snacking. Another popular dish is "mugombakapini," a stiff porridge blending Mahangu flour with boiled dry Bambara groundnut seeds.

Furthermore, Bambara groundnuts can be roasted, ground into flour and used to prepare "rutura," an instant porridge. Unfortunately, finding recipes for these essential Namibian dishes is challenging, as much of this culinary knowledge is not well-documented. While the variety of foods prepared in Kavango may be fewer than in other African countries, it is worth noting that similar dishes are prepared in various regions. For instance, Eastern Africa has employed Bambara flour to create thick and thin porridge (Mubaiwa *et al*., 2017). In Eastern Nigeria, dry Bambara groundnut seeds are ground into a powder and used to make a delicacy called "okra." Before cooking, this dish is wrapped in banana leaves and is a staple for many low-socioeconomic families, serving as breakfast, lunch, or dinner by a typical low socioeconomic family (Obidiebube *et al*., 2019).

Inputs for Bambara groundnut farming

The Chi-square test revealed a statistically significant association (χ^2 = 3.592; P≤0.058) concerning farmers' use of fertilizer in the two constituencies. This indicates a difference in the application of fertilizer rates between the two constituencies. Notably, all farmers in the Mukwe constituency reported not using fertilizer in their fields, while 8.7% of farmers in the Ndiyona constituency indicated using fertilizer. Those farmers who reported using fertilizer were identified as participants in the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) programs. They were provided with NPK fertilizer and received training on its proper use, as detailed in Table 5.

The conclusions regarding fertilizer consumption are comparable to those of Horn *et al*. (2015), who reported that most farmers cannot access synthetic fertilizers to enhance soil fertility. Furthermore, these fertilizers are believed to increase soil acidity and may result in a high reliance on N fertilizer for crop production (Lindström and

Table 5: Farmers' response on fertilizer usage in the two constituencies in Kavango East Region.

Constituenc	% of farmers with fertilizer usage	% of farmers without fertilizer usage	df	χ^2	*P*-value
Mukwe	0	100	1	3.592	0.058
Ndiyona	8.7	91.3			

Table 6: Bambara groundnut production constraints in the two constituencies (Mukwe and Ndiyona) in Kavango East.

Bambara groundnut production constraints	Constituency		df	χ^2	*P*-value
	% of farmers in Mukwe	% of farmers in Ndiyona			
High cost					
fertilizer	0.0	8.7			
seed	37.5	30.4	2	3.693	0.158
labor	62.5	60.9			
Field pest					
Stem borer	7.5	4.3			
Greenburg's	0.0	21.7	3	13.719	0.003
Aphids (runwamaghadhi)	92.5	65.2			
Stem and stalk borers	0.0	8.7			



Fig 1: Aphids (left) and termites (right), pests observed among Bambara groundnut during growing and harvesting periods in Kavango.

Mousavi, 2020). As a result, more efficient techniques are required. One of the techniques is using rhizobial inoculants to increase leguminous crop production while reducing the need for synthetic nitrogen fertilizer (Laurette *et al*., 2015). Rhizobial inoculation is a less expensive and often more successful agricultural strategy for guaranteeing adequate nitrogen supply (Yakubu *et al*., 2010). Many strains of *Bradyrhizobiun* symbionts were already isolated from Bambara groundnut nodules in Namibia and some were even heat-tolerant (Grönemeyer and Reinhold-Hurek, 2018).

Bambara groundnut production constraints

The significant production constraints in Bambara groundnut cultivation were identified as high costs and field pests, as indicated in Table 6. In the Mukwe constituency, 62.5% of farmers reported high labor costs as a constraint and 37.5% mentioned high seed costs. In the Ndiyona constituency, 60.9% of farmers cited high labor costs, 30.4% pointed to high seed costs and 8.7% mentioned high fertilizer costs as limitations to Bambara groundnut production. The study's findings are consistent with previous research, emphasizing that Bambara groundnut production in Kavango Region faces various challenges. Some of the farmers claimed that the reasons for not expanding their production was the lack of necessary harvesting equipment. Some claimed that the cultivation by hand hoeing was limiting their production and urged for government to avail tractors or oxen to them. Where there is no means of labour to land tilling, farmers reserve their energy for cultivating other vital crops like Mahangu instead of Bambara groundnut. Grönemeyer and Reinhold-Hurek (2018) reported that several factors, such as unpredictable yields, the danger of crop failure and a lack of financial resources, contribute to food insecurity in these rain-fed agriculture systems in the Kavango Region. Equally important, uunpredictable weather, a lack of improved

varieties was cited as constraints in Uganda (Kakeeto *et al*., 2019). Farmers also need to be provided with the required resources to maximize productivity and use microbial inoculants to boost production or yield. According to Mfilinge *et al*. (2014) and Santos *et al*. (2019), using appropriate inoculant strains in nitrogen-deficient soils may provide an excellent opportunity for increasing legume growth and development.

There was a statistically significant association between constituencies and field pests (χ^2 = 13.719; P≤0.003), that is, the response to field pests as a contributing factor to yield losses every year was different among the two constituencies (Table 6). Most farmers in both constituencies deal with aphids, known locally as "runwamaghadhi" (Fig 1). In addition, they also reported rodents, termites, ants and cutworms (*Agrotis*) as significant pests in their field crops. Similar to this finding, Mukakalisa (2010) and Tlankka *et al*. (2020) found that insect pests such as aphids (*Aphis* sp.), leafhoppers (*Hilda patruelis*) and bruchids (*Callosobruchus maculatus* and *C. subinnotatus*) limit the output of Bambara groundnuts. Therefore, efficient agriculturally beneficial microbes (microbial inoculants) have the potential to play a role in sustainable crop production due to their immense plant growth promoting attributes, as well as plant protection metabolites (biopesticides) (Singh *et al*., 2016; Gedamu *et al*., 2021). Biopesticides will significantly benefit farmers as they are less expensive and safer than chemical pesticides (Babalola *et al*., 2017).

CONCLUSION

This study offered valuable insights into Bambara groundnut farming systems, farmers' preferred seed colors, reasons behind their choices, input requirements and production constraints in Namibia's Kavango East Region. It highlighted the significance of better seeds and essential production inputs, including fertile soils, in increasing Bambara groundnut yields. A healthy and productive soil is vital for agricultural sustainability, food security and renewable energy. The study suggests that modern technology, such as inoculants, can play a crucial role in improving Bambara groundnut production and meeting the needs of the growing global population. It envisions the Kavango Region as a potential hub for Bambara groundnut production, capable of supplying Namibia and neighboring regions. However, achieving this potential depends on adopting modern production practices, providing quality seeds and supporting Bambara groundnut productivity with the necessary inputs.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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