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Missanga, Julius

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Research Article

Julius S. Missanga*, Pavithravani B. Venkataramana, Patrick A. Ndakidemi

Lablab purpureus: Analysis of landraces cultivation and distribution, farming systems, and some climatic trends in production areas in Tanzania

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Abstract: Lablab is a multifunctional crop that is underutilized in Africa. This study was performed to assess Lablab landraces cultivation and distribution, farming systems, and some climatic trends in Lablab production areas in Tanzania. A socio-economic survey was engaged to locate the main production areas using Global Positioning System, while participatory research tools were used to assess farming systems, practices, and challenges perceived in Lablab production. Some weather data were collected to establish climatic trends in Lablab production areas. The study revealed a wide cultivation and distribution of Lablab landraces in five agro-ecological zones with some variations. These variations were influenced by market demand for Lablab in Kenya and its role in subsistence farming. Lablab was mainly produced for conservation agriculture and enhanced soil fertility (27.9%), marketing (22.1%), livestock feeding (21.5%), food during drought conditions (15.4%), traditional purposes (7.4%), regular consumption (3.8%), and other minor uses (1.8%) varied significantly across the zones (χ^2 = 37.639, p = 0.038). The farming systems included intercropping (59.0%), monocropping (31.0%), home based gardening (5.0%), crop rotation (3.0%), and relaying cropping (2.0%) with no significant difference across the zones (χ^2 = 15.049, p = 0.314). A wide range of farmers' practices were noted in Lablab production zone-wise. Unavailability of improved varieties and poor market channels were the farmers' key challenges in Lablab production. It was further noticed that Lablab was mainly produced in areas with dry conditions. Finally, it was suggested that effort should be enhanced to improve genetic resource conservation, value addition, and market channels to other countries while developing improved varieties in terms of high yielding and drought tolerance.

Keywords: *Lablab purpureus*, landraces, farming systems, agro-ecological zones, climatic trends

*** Corresponding author: Julius S. Missanga,** School of Life Science and Bio-engineering, The Nelson Mandela African Institution of Science and Technology (NM-AIST), P. O. Box 447, Arusha, Tanzania; Biotechnology and Bioinformatics Unit, Department of Biology, University of Dodoma (UDOM), P. O Box 338, Dodoma, Tanzania, e-mail: missangaj@nm-aist.ac.tz, julius.missanga@udom.ac.tz, jmissanga@gmail.com
Pavithravani B. Venkataramana: School of Life Science and Bio-engineering, The Nelson Mandela African Institution of Science and Technology (NM-AIST), P. O. Box 447, Arusha, Tanzania, e-mail: pavithravani.venkataramana@nm-aist.ac.tz
Patrick A. Ndakidemi: School of Life Science and Bio-engineering, The Nelson Mandela African Institution of Science and Technology (NM-AIST), P. O. Box 447, Arusha, Tanzania, e-mail: patrick.ndakidemi@nm-aist.ac.tz
ORCID: Julius S. Missanga 0000-0002-8591-7293

1 Introduction

One-third of food resources produced for human consumption is lost in the field due to drought stress [1]. The most important strategy to reduce such amount of food losses is the use of drought-resilient crops that can resist yield losses when grown in stressful environments [2]. Lablab (*Lablab purpureus* L. Sweet) is a multi-purpose crop essential for human consumption, livestock feeding, conservation agriculture, enhanced soil fertility, and income generation [3]. Although it has been regarded as an orphan crop in many areas in Africa including Tanzania [4], Lablab is the potential drought-resilient crop able to remain green during persistent drought conditions [5,6]. It is increasingly gaining popularity as a food and cash crop among farmers in East Africa, especially in marginal rainfall areas where climatic conditions are not favorable for the consistent growth of other legumes [7]. Thus, Lablab out-yields other relative crops such as common bean, cowpeas, and pigeon peas [8]. During persistent drought when other crops are no longer in the field, these farmers have mostly been depending on Lablab for their livelihood and income.

To improve Lablab production in Africa, a tremendous work is being done by the Nelson Mandela African Institution of Science and Technology (NM-AIST), Tanzania with collaborative institutions such as the University of Dodoma, Tanzania to enhance knowledge, research, and development of the Lablab crop. The work has a role to ensure that Lablab is well known for broader utilization and commercialization. This is because Lablab is a neglected crop in Africa that faces several challenges. Lack of improved varieties, insect pests' damage, disease infestation, lack of market channels, and poor agronomic practices are part of these challenges [9,10]. Lablab has also been given a low priority among consumers due to long cooking time and anti-nutritional factors [11]. These challenges have created a need for enhancing crop genetic resources in Africa to improve breeding traits. More than 3,000 Lablab accessions were collected worldwide with the largest reserve existing in India [10]. In order to improve Lablab gene-bank in the country and Africa at large, collections of local landraces from farmers become the key strategy [12]. Since there is a high risk of extinction among crop species due to anthropogenic activities and climatic factors [13,14], their conservation becomes very essential [15]. However, it requires an engagement of various stakeholders in conservation programs [16,17] especially farmers as their knowledge could be easily integrated and improved for sustainable development of the crop [18,19].

The Participatory Rural Appraisal (PRA) is a rapid and cost-effective tool used to collect farmers' information on crop production. Collection of landraces for their conservation also becomes easier through the PRA [20]. Since there is limited information about Lablab production in Tanzania, this study was undertaken to assess Lablab landraces cultivation and distribution, farming systems, and some climatic trends in Lablab production areas in the country.

2 Materials and methods

2.1 Study site selection

This study began by identifying Lablab major production areas (regions and districts) in the country based on published [6,21–23] and unpublished data as well as information from agricultural and extension units. Thus, from five agro-ecological zones [24], seventeen districts, Same and Mwanga (Northern arid zone); Arumeru, Karatu, Simanjiro, Babati, and Hanang (Northern highland zone); Dodoma, Mpwapwa, Kondoa, and Singida (Central zone); Kilosa, Mvomero, and Gairo (Eastern zone); as well as Kilindi, Korogwe, and Handeni (Coastal zone) were recognized as Lablab main production areas in the country.

The study engaged two steps to reach to the wards, villages and farmers potential in Lablab production. The first step involved a socio-economic survey to explore wards and villages suitable for production while recording their positions by Global Positioning System (GPS) along with some information on landraces cultivation and their characteristics.

The next step involved participatory research with farmers to assess the use of Lablab, their farming systems, practices, and challenges perceived in Lablab production. In this section, two districts from each zone and two wards from each district were selected for the study based on their production potential i.e., *purposive sampling*. Finally, one village from each ward was selected for the study again based on their farming potential. The districts, wards, and villages selected for the study were first arranged in their respective zones as represented in Table 1.

This study was conducted between August, 2019 and February, 2020 to coincide with a range of production and post-harvest activities.

2.2 Research processes

After exploring the wards and village potential in Lablab production, information on landraces cultivation such as level and farmers' area (ha) of production, characteristics of landraces, and seed color were recorded from the farmers. These records on Lablab landraces were supported by observation made to the farmers' storage, field, and market. The level of production was ranked as +++ (high), ++ (medium), and + (low) based on the number of villages involved in production as described by Singh and Abhilash [25]. The average farmers' area of production was ranked as >5, 2–4, 1–2, and <1 ha. The records also included various sectors involved in Lablab crop improvement and their roles in development of the crop. Collections of Lablab landraces (from farmers) and germplasm (from gene-banks and research institutes) involved at least half a kg of seeds that were transported to the NM-AIST, Arusha for conservation and further studies.

Table 1: Lablab production areas along with their production information in five agro-ecological production zones

Zone (5)	Districts (17)	Wards (80) and villages (98)	Level of prodn.	Area (ha) of prodn*	Seed color	Qualities of landraces	Local names	*n*
(i) Northern arid zone	Same	Gavao-saweni, Mabilioni, Hedaru, Makanya, Same, Kavambughu, Vudee, Kisiwani, Bangalala, Maore, and Kisima	+++	>5	Black	– Withstand long climatic stress – High marketability	Ngwasha, Shughu	3
	Mwanga	Kigonigoni, Mgagao, Kirya, Kilomeni, Kileo, Kwakoa, Kivulini, and Lembeni	++	2–4		– Semi-indeterminate		2
(ii) Northern highland zone	Arumeru	Ngarenanyuki, Kikatiti, Mbuguni, Maroroni, Nduruma, Bwawani, Kikwe, Makiba, Kalangai, Likamba, Majengo, Malula, Kisongo, Lengijave, and Oldonyo-sambu	+++			– Variable yielding cultivars – Short running sp.	Mmba, Ingwara	3
	Babati	Gallapo, Magugu, Kiru, Dareda, Bashnet, and Mamire			Black, white, cream, and	– Bitter in taste – Few disease attacks	Ngwari, Marimba	3
	Hanang	Nangwa, Katesh, Mulbadaw, Bassotu, Laghanga, Getanuwas, and Endasaki	++		brown	– Require little rainfall – Pods of large size	Losir-gwara, Ingwara	2
	Karatu	Qurus, Mang'ola, Rhotia, and Mbulumbulu			Black	– Susceptible to a range of		3
	Simanjiro	Loiborsiret, Komolo, Loswaki, and Emboreet	+++	>5		field insect pests		3
(iii) Central zone	Dodoma	Mvumi, Mpunguzi, Mbabala, Hombolo, Kikombo, Bihawana, Makutupora, Veyula, and Chihanga	+	<1	White, cream, brown, red, and	– Tolerant to high temp – Short cooking interval	Fwiriri, Fwiri	5
	Kondoa	Bumbuta, Busi, Itaswi, and Mondo	++	1–2	black	– Palatable and nutritious		4
	Mpwapwa	Godegode and Mlunduzi	+	< 1		– High yielding preferred by		2
	Singida	Mwasauya and Ilongero				storage pests		2
(iv) Eastern zone	Kilosa	Chanzuru, Mabwerebwere, Kivungu, and Ulaya Kibaoni				– Germinate in wide range of soils	Firiwili, Mafiri	4
	Gairo	Kibedya, Idibo, Iyogwe, Mkalama, Msingisi, and Rubeho	++	1–2		– Extended root system with many nodules		5
	Mvomero	Makuyu, Kanga, and Kikeo	+	<1				3
(v) Coastal zone	Kilindi	Jaila, Mkindi, Negero, and Mvungwe	++	2–4	Black, white, cream, and brown	– Climbing/twining plants – High biomass	Magobe, Nkwansha	3
	Korogwe	Bungu, Mazinde, Mkumbara, Mombo, Mlembule, Magamba, and Kwalukonge	+	<1	White, cream, brown, and	– Indeterminate and late flowering cultivars		3
	Handeni	Mkata and Misima			black	– Intermittent flowering		
		Total number (*n*) of Lablab landraces collected from the farmers						**50**

Level of production is reported as +++ (high), ++ (medium), and + (low) depending on wards and villages involved in production.
*Area of production: Refers to an average area (ha) of production per farmer; n – number of Lablab landraces collected from the farmers as per each district.

Some participatory research tools included key informant (KI) interviews, focus group discussions (FGDs), and semi-structured questionnaires. The KI interviews (n = 6) were employed in each zone to involve the district agricultural officers, research scientists, village and sub-village leaders, extension workers, officers from nongovernmental organizations (NGOs), and other stakeholders in production such as seed and fertilizer companies, processors, and distributors depending on their availability. The FGDs (n = 5) with key farmers from different households were involved in each zone. Their discussion was completed through a checklist of farming systems and farmers' practices to supplement the information in questionnaires pre-tested in pilot study areas for evaluating the reliability and validity of the survey instruments. Based on the Cochran formula, $N = [Z^2(p)\ (1–p)/C^2]$, where Z = 1.96, estimated proportion (p) = 0.5, and C = confidence level (95%) [26], random sampling was employed to the farmers' household groups to obtain a sample population for questionnaire assessment. About 390 households from the entire area of study (78 per zone) were assessed for single-answer responses. Two enumerators were trained for the work in each zone.

Weather data i.e., daily rainfall (mm) and maximum and minimum temperatures (°C) were collected from zonal representative of Tanzania Meteorological Authority (TMA) stations for a period of 5 years (2014–2018). The data were collected from Same (Northern arid zone), Arusha Airport (Northern highland zone), Dodoma (Central zone), Kilosa (Eastern zone), and Handeni (Coastal zone) to establish climatic trends in Lablab production in Tanzania.

2.3 Data analysis

Wards and villages identified as Lablab production areas were organized in their respective agro-ecological zones and information on farmers' landraces, seed colors, level, and area of production were aligned at district level. Their GPS coordinates were processed for mapping through "Garmin Map-source and ArcMap 10" software. Farmers' landraces along with their seed colors were represented in a map using "ArcGIS mapping" software (https://www.esri.com). A relationship between agro-ecological zones [24] and the areas growing Lablab in Tanzania as per the present study was established through a new map.

Farmers' information collected through questionnaires was grouped, coded, and analyzed using the statistical package IBM SPSS Statistic 25.0 (New York, USA). Some statistical tools for descriptive statistics such as crosstabs, counts (frequencies), percentages (%), and Chi-square (χ^2) were used to analyze the variations in farmers' data zone-wise. The χ^2 test was determined at a 95% confidence interval [27]. Linear correlation (bivariate Pearson) was finally performed to study the relationship between the selected farmers' information.

Weather data collected from the zonal representative TMA stations were processed in excel to establish the climatic trends in rainfall and temperature monthly-wise for a selected period of time.

Informed consent: Informed consent has been obtained from all individuals included in this study.

Ethical approval: The conducted research is not related to either human or animal use.

3 Results

3.1 Lablab landraces cultivation and distribution in Tanzania

3.1.1 Level and farmers' areas in Lablab production across the zones

Table 1 demonstrated a wide cultivation and distribution of Lablab landraces in Tanzania. 5 agro-ecological zones, 17 districts, 80 wards, and 98 villages were involved in Lablab production in the country. The areas involved in Lablab production in the country had also a wide range (320–1,956 masl) of altitudes. Table 1 showed also variations in the level and farmers' area in Lablab production in the country. A high-level (+++) and a large area of Lablab production (>5 ha) were more noted in the northern arid and highland zones compared to the rest of the country, where low (<1 ha) and scattered (+) production were found. It further showed different characteristics of Lablab landraces at the district level.

Different Lablab seed colors (Figure 1) i.e., black colored seeds (dominating in northern zones) and all types of colored seeds i.e., black, white, cream, brown, and red colors (in other zones) established a great Lablab seed color diversity in the country (Figure 2). A low degree of seed color diversity was observed in Same and Mwanga districts (in the northern arid zone) as well as in Arumeru, Karatu, and Simanjiro districts (in the northern highland zone). However, medium degree of seed color diversity was observed in Babati and Hanang districts (in the northern highland zone) and Kilindi

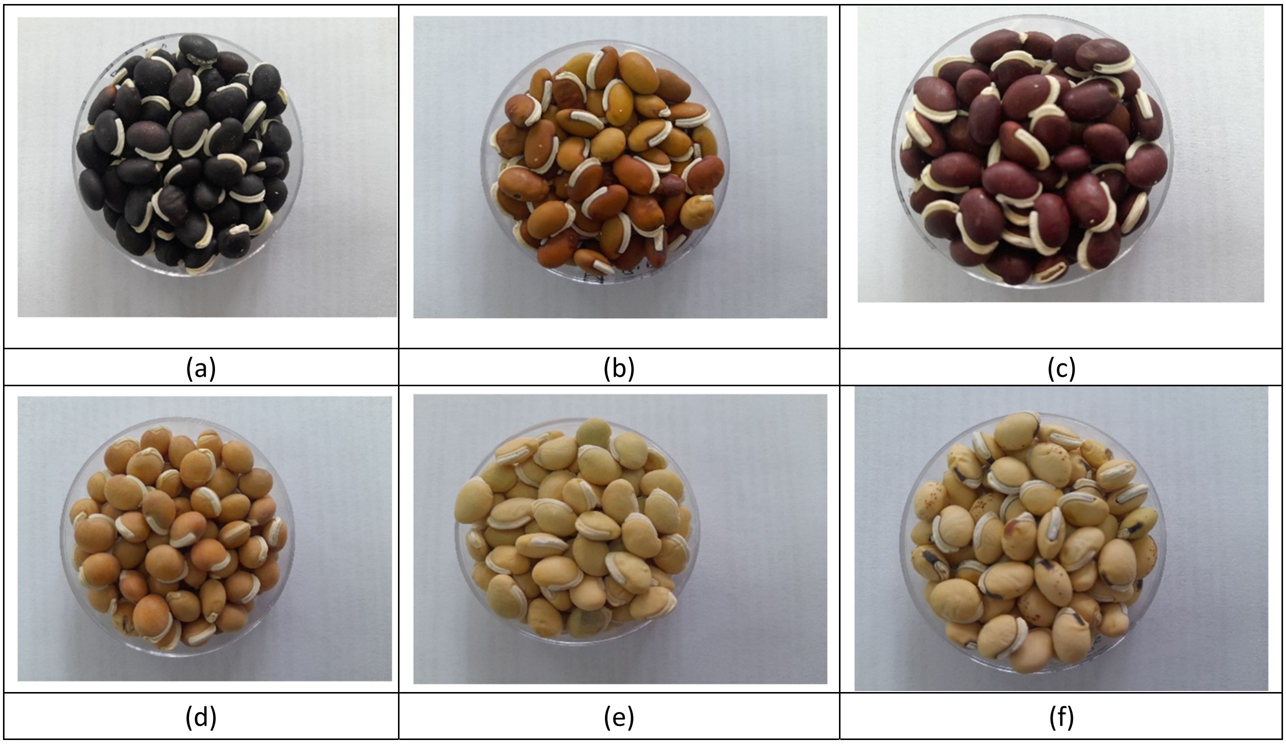

Figure 1: The common-colored seeds of the collected Lablab landraces illustrated using a polystyrene Petri-dish. (a) Black colored seeds, (b) brown colored seeds, (c) red colored seeds, (d) cream colored seeds, (e) white colored seeds, and (f) white colored seeds with black hilum (eye) edges (diameter of the Petri-dish: 65 mm × 15 mm).

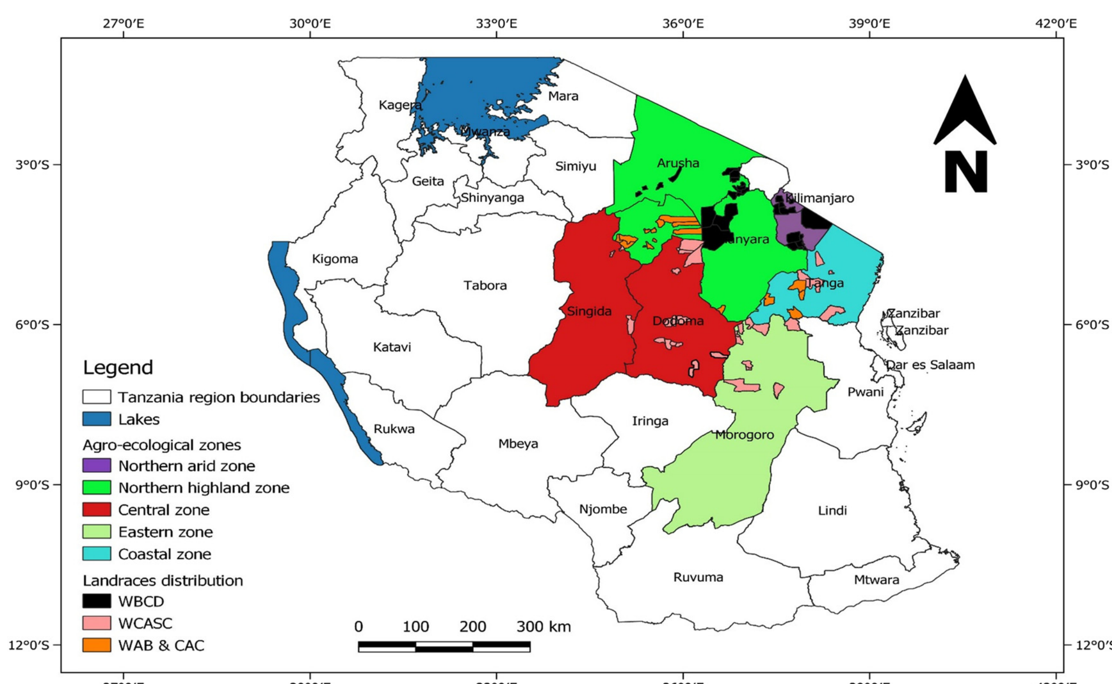

Figure 2: A map of Tanzania showing potential wards and villages in Lablab production along with seed color diversity in each of five Lablab agro-ecological production zone: WBCD refers to the wards with black seeded cultivars dominating; WCASC refers to the wards with cultivars of all colored seeds; and WAB and CAC refers to the wards with high availability of black cultivars and less of other cultivars.

district (in the coastal zone) as they had a high presence of black seeded cultivars along with other colored seeds. The rest of the districts in the coastal, central, and eastern zones had the highest degree of seed color diversity due to the presence of Lablab landraces with all types of seed colors.

Such a wide cultivation and distribution of Lablab landraces in the country along with their great genetic variations were revealed by different landraces characteristics and their vernacular names across the production areas. Lablab was mainly grown in areas with arid and semi-arid climatic conditions (Figure 3).

Overall, 50 landraces were collected and maintained at the NM-AIST gene bank for further research.

3.1.2 Sectors involved in Lablab crop improvement

Various sectors and their roles in Lablab crop improvement are demonstrated in Table 2. These institutions and organizations were more found in the northern highland zone compared to other zones. Similarly, the northern highland zone had more Lablab gene banks than the rest of the zones. Among the roles of the institutions or organizations on Lablab crop improvement, value addition was not given a high priority. This was reflected in the farmers' marketing system where Lablab was mainly sold as dry grains. In some local and town markets, Lablab was sold through containers famously known as "sado" while its transportation to Kenya involved mainly bags.

Collection of Lablab germplasm in the country involved also various plant gene-banks such as the National Plant Genetic Resource Centre (NPGRC) (20) in Arusha, and the plant/pasture unit at Tanzania Livestock Research Institute (TALIRI), Mpwapwa (2) in Dodoma. The collected Lablab germplasm were also transported and maintained at the NM-AIST gene bank for further research.

3.2 Farming systems and main challenges in Lablab production

3.2.1 Household demographic information

Table 3 shows the farmers' demographic information across the zones. In the aspect of sex of the Lablab growing famers, the males were generally fewer compared to females, while their proportion varied significantly across the zones ($p < 0.001$). An exception was noted in northern arid and northern highland zones where males were more than females. A significant difference ($p < 0.001$) in age was also observed across the

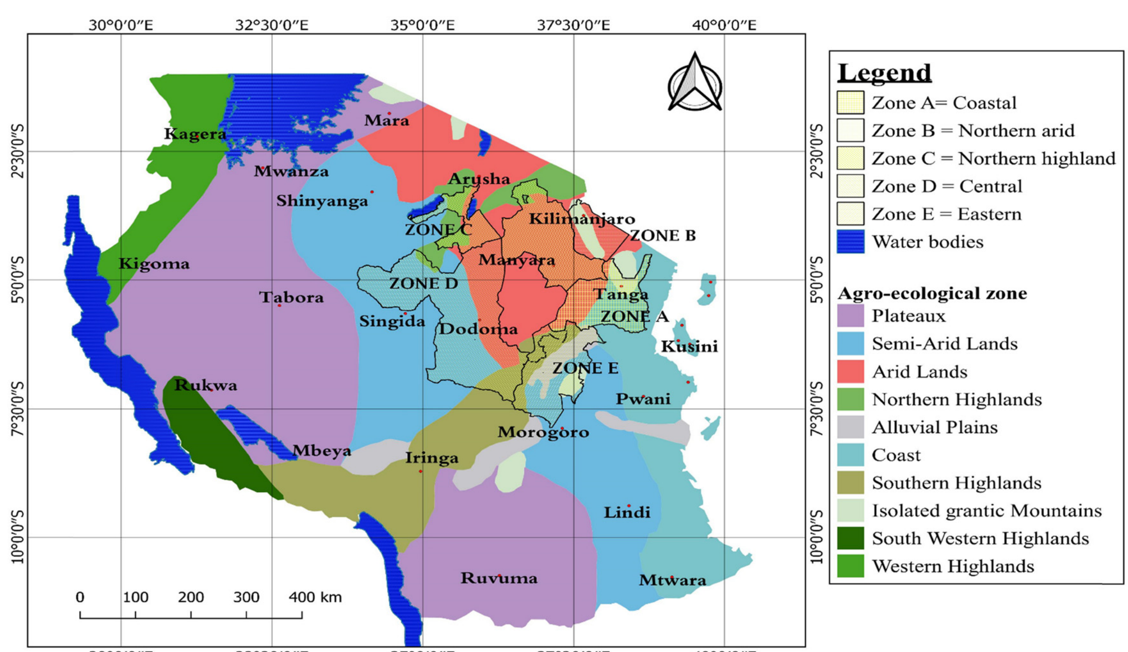

Figure 3: A new map showing the relationship between agro-ecological zones of Tanzania as per MAFSC [24] and areas growing Lablab in Tanzania as per this survey study. All the Lablab growing areas were located in arid or semi-arid lands to suffice findings that Lablab does not need much rainfall [6].

Table 2: Different sectors on Lablab crop improvement across the zones

Zone	Institutions and organizations	Roles	Germplasm
Northern arid zone	Same-Mwanga Environmental Conservation Advisory Organization (SMECAO)	Environmental conservation; Conservation agriculture	
Northern highland zone	NM-AIST, Arusha (through STOL Project)	Research; training; gene-bank	*378–450
	World vegetable center, Arusha	Research; training; gene-bank	73
	ECHO community, Arusha	Conservation; gene-bank	32
	NPGRC, Arusha	National gene-bank	27
	TARI-Selian, Arusha	Research; conservation agric.	
	RECODA, Arusha	Conservation; extension services	
	World Vision Tanzania (WVT), Arusha	Conservation agriculture	
	MVIWA-ARUSHA	Sustainable agriculture	
	A Climate-resilient Model for Maasai Steppe Pastoralists (ECOBOMA), Arusha	Conservation; extension services	
Central zone	TALIRI, Mpwapwa	Research; Gene-bank	2
	Diocese of Central Tanganyika (DCT), Dodoma	Conservation agriculture	
	TARI-Hombolo; TARI-Makutupora, Dodoma	Research; conservation	
Eastern zone	Sokoine University of Agriculture (SUA)	Research; conservation	
	TARI-Ilonga, Kilosa	Extension services	
Coastal zone	TALIRI-Tanga	Research; conservation	1
	TARI-Mlingano, Tanga	Research; conservation	
Total number of Lablab germplasm conserved in different gene-bank in the country			*513–585

TARI – Tanzania Agricultural Research Institute; NPGRC – National Plant Genetic Resource Centre; RECODA – Research, Community & Organizational Development Associates; TARILI – Tanzania Livestock Research Institute.
STOL – Stress Tolerant Orphan Legumes. *After collection of Lablab landraces (50) from the farmers and its germplasm (22) from various institutions and organizations, number of Lablab accessions maintained at the Nelson Mandela African Institution of Science and Technology (NM-AIST), Arusha, Tanzania reached 450 to become the largest Lablab gene-bank in Africa. Total number of Lablab germplasm available in the country also reached 585.

Table 3: Households' demographic data from five Lablab agro-ecological production zones

Farmers' data (%) across the zones		Northern arid	Northern highland	Central	Eastern	Coastal	Average (n = 390)	Chi-square and p-value
(i) Sex	Male farmers	67.9	59.0	25.6	32.1	35.9	44.1	χ^2 = 42.499;
	Female farmers	32.1	41.0	74.4	67.9	65.1	55.9	p = 0.000; df = 4
(ii) Range of age (in years)	20–29	7.7	10.3	5.1	5.1	3.8	6.4	χ^2 = 33.649;
	30–39	19.2	17.9	14.1	12.8	12.8	15.4	p = 0.001; df = 12
	40–49	24.4	28.2	57.7	56.4	46.2	42.6	
	>49	48.7	43.6	23.1	25.6	37.2	35.6	
(iii) Level of education	Informal	7.7	9.0	17.9	12.8	15.4	12.6	χ^2 = 18.099;
	Primary	51.3	52.6	65.4	61.5	52.6	56.7	p = 0.113; df = 12
	Secondary	23.1	25.6	10.3	16.7	21.8	19.5	
	College	17.9	12.8	6.4	9.0	10.3	11.3	
(iv) Occupation	Crop production	29.5	52.6	28.2	33.3	26.9	34.1	χ^2 = 16.747;
	Livestock keeping	17.9	14.1	17.9	21.8	21.8	18.7	p = 0.033; df = 8
	Mixed farming	52.6	33.3	53.8	44.9	51.3	47.2	
(v) Experience (in years)	1–5	11.5	11.5	3.8	5.1	3.8	7.2	χ^2 = 21.282;
	6–10	16.7	17.9	23.1	24.4	24.4	21.3	p = 0.046; df = 12
	11–15	28.2	26.9	43.6	42.3	43.6	36.9	
	>15	43.6	43.6	29.5	28.2	28.2	34.6	

zones. The oldest farmers were found to be more in the northern arid and highland zones while the youngest ones were more in the coastal zone. Different levels of education were observed among the farmers, showing no significant variation across the zones ($p = 0.113$). However, Lablab was significantly grown in line with all farmers' occupation ($p = 0.033$) across the zones. The farmers involved in Lablab production as a main crop were more noted in the northern highland zone and less in the rest of the zones. Those who utilized it for livestock were very few compared to the mixed farming, across the zones. The farmers had also a broad scope of experience in Lablab production that varied significantly ($p = 0.046$) across the zones. While a majority of farmers had > 10 years of experience, few of them were growing Lablab for about 5 years. The short and long-term experienced farmers were more in the northern arid and highland zones than the rest of the zones.

A correlation between farmers' experience in Lablab production and some demographic factors showed that their experience was negatively influenced by sex ($r = -0.111^*$), and ages ($r = -0.104^*$). Therefore, sex and age were noted as significant ($p = 0.029$ and 0.040) and correlating factors for farmers' experience, respectively. The result further showed a direct significant association between farmers' experience and level of education ($r = -0.556^{**}$) at $p < 0.001$.

3.2.2 Farming systems in Lablab production

Farming systems practiced by farmers in Lablab production across the agro-ecological zones of Tanzania (Figure 4) were intercropping, mono-cropping, home-based gardening, crop rotation, and relay cropping with no significant variation ($p = 0.314$) across the zones.

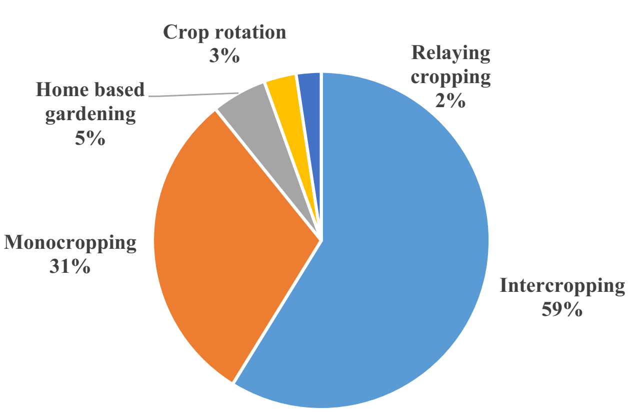

Figure 4: Farming systems practiced in Lablab production in Tanzania ($\chi^2 = 15.049$; $p = 0.314$).

3.2.3 Farmers' uses and preferences on Lablab

Table 4 demonstrates farmers' main uses and preferences on Lablab across the zones. Lablab main uses varied significantly ($p = 0.038$) across the zones (Table 4(i)). Lablab was cultivated for the purpose of conservation agriculture and to enhance soil fertility in the central, eastern, and coastal zones, while in northern arid and highland zones, it was grown for grains, as marketing was their main interest. Lablab was also fed to Livestock mainly in the central, eastern, and coastal zones. Lablab was consumed in various scenarios. In central zone it was considered and consumed as food during drought conditions, while it was considered as traditional food, regular food, and medicine in northern arid and highland zones. The farmers' use on Lablab influenced the selection of their landraces. Seed parameters (Table 4(ii)) were the main criteria used by farmers to select their landraces and they did not vary significantly ($p = 0.975$) across the zones. Among the seed parameters, the color of the seeds (Table 4(iii)) was the farmers' seed selection criteria for various uses, although it did not have significant difference ($p = 0.979$) across the zones. The color of the seeds had also crucial influence on consumers' preference as well as on the market choices. The preference of white or cream colored seeds for food varied significantly across the zones ($p < 0.001$). Central, eastern, and coastal zones had more farmers preferring white or cream colored seeds for food (Table 4(iv)). Contrary to that, the preference for black colored seeds for the market especially in the northern arid and highland zones showed no significant difference across the zones ($p = 0.320$) (Table 4(v)).

3.2.4 Some farmers' practices in Lablab production

Table 5 demonstrated some practices followed by farmers in Lablab production. Their sources of seed in Table 5(i) had no significant variation across the zones ($p = 0.782$). The Lablab production season (Table 5(ii)) was changing between January and April with significant variation ($p < 0.000$) across the zones. The farmers who were growing Lablab in January were only found in the central zone and their numbers increased in February. Most farmers across the zone preferred to grow Lablab in March. Only few farmers especially from the eastern and northern arid zones were growing it in April. It took around 4–6 months

Table 4: Farmers' main use of Lablab and their preferences across their agro-ecological production zones

	(i) **Main uses of Lablab according to the farmers**								
Main uses	Cons. agriculture and soil fertility	Marketing	Livestock feeding	Food during drought cond.	Traditional food resources	Regular human food	Other minor uses	$n = 390$	$\chi^2 = 37.639$; $p = 0.038$; df = 24
Percentage	27.9	22.1	21.5	15.4	7.4	3.8	1.8	100	
	(ii) **Farmers' preferred criteria for Lablab cultivars' selection**								
Selection criteria	Seed parameters	Pods parameters	Growth habit	Growth cycle	$n = 390$	$\chi^2 = 4.376$; $p = 0.975$; df = 12			
Percentage	41.5	27.9	20.0	10.5	100				
	(iii) **Farmers' seed selection criteria**								
Selection criteria	Seed color	Seed damage	Seed size	Seed shape	$n = 390$	$\chi^2 = 4.244$; $p = 0.979$; df = 12			
Percentage	43.3	28.5	17.9	10.3	100				
	(iv) **Seeds color preferred for food**								
Colored seeds	White/cream	Black	Brown	Red	Other colors	$n = 390$	$\chi^2 = 38.031$;		
Percentage	46.7	36.9	9.5	4.9	2.1	100	$p = 0.001$; df = 16		
	(v) **Seeds color preferred for the market**								
Colored seeds	Black	White/cream	Brown	Red	Other colors	$n = 390$	$\chi^2 = 18.061$;		
Percentage	64.9	22.6	6.9	3.6	2.1	100	$p = 0.320$; df = 16		

Table 5: Some farmers' practices in Lablab production across the zone

	(i) **Main sources of seeds in Lablab production**							
Sources of seeds	Farmers' own savings	Neighbors and relatives	Purchased from market	Donated by projects	Research institutions	Middlemen and salesmen	n = 390	χ^2 = 14.901; p = 0.782; df = 20
Percentage	41.3	26.4	16.4	8.2	4.9	2.8	100	
	(ii) **Growing season in Lablab production**							
Season	January	February	March	April	n = 390	χ^2 = 289.571; p = 0.000; df = 12		
Percentage	14.4	32.1	45.9	7.7	100			
	(iii) **Harvesting season in Lablab production**							
Season	June	July	August	September	n = 390	χ^2 = 174.901; p = 0.000; df = 12		
Percentage	2.3	25.9	56.9	14.9	100			
	(iv) **Storage period of Lablab harvested grains**							
Storage period	0–3	3–6	6–12	>12	n = 390	χ^2 = 21.937; p = 0.038; df = 12		
Percentage	43.8	27.2	17.7	11.3	100			
	(v) **Main market channels used by farmers to sell their grains**							
Main market channel	Markets in towns and cities	Middlemen and salesmen	Village markets	Fellow farmers	n = 390	χ^2 = 22.382; p = 0.033; df = 12		
Percentage	39.5	34.9	17.2	8.5	100			
	(vi) **Main sources of farmers' extension services in Lablab production**							
Main sources of information	Shared experience	Ext. agents and exhibitions	NGOs	Research institutions	Various media	n = 390	χ^2 = 5.46; p = 0.993; df = 16	
Percentage	33.1	28.7	17.4	16.7	4.1	100		

to start harvesting Lablab depending on the agro-ecological zones. The harvest season (Table 5(iii)) varied significantly ($p < 0.001$) across the zones. The first harvest was noted in June for the farmers in the central zone. Harvesting of the crop in July involved only a few farmers, especially from the central and coastal zones. Majority of farmers across the zone were harvesting Lablab in August. However, very few farmers, especially from the eastern zone were harvesting it in September. Lablab harvested grains were stored for different periods (Table 5(iv)). The storage periods varied significantly ($p = 0.038$) across the zones. Storage for up to 3 or 6 months was observed in northern highland and northern arid zones, while storage for 6–12 or >12 months was more found in other zones. Table 5(v) demonstrated that the main market channels in Lablab production varied significantly ($p = 0.033$) across the zones. The northern arid zone and northern highland zone had more middlemen and organized salesmen, while in rest of the zones, the farmers relied more on markets in towns and cities. Few farmers, especially from the eastern and central zones were selling their harvest in local markets and among themselves. Table 5(vi) demonstrated that the farmers' main sources of extension services in Lablab production did not vary significantly ($p = 0.993$) across the zones.

3.2.5 Main challenges perceived by farmers' in Lablab production

Main challenges perceived by farmers in Lablab production are demonstrated in Figure 5. These challenges included lack of improved varieties especially unavailability of high yielding and drought-tolerant varieties, insect pests' damage, poor market channels, lack of quality seeds, poor agronomic practices, high cost of agro-chemicals, and other minor challenges such as flowers dropping, disease infestation, and poor storage facilities. However, no significant difference ($p = 0.994$) between these challenges was noted across the zones.

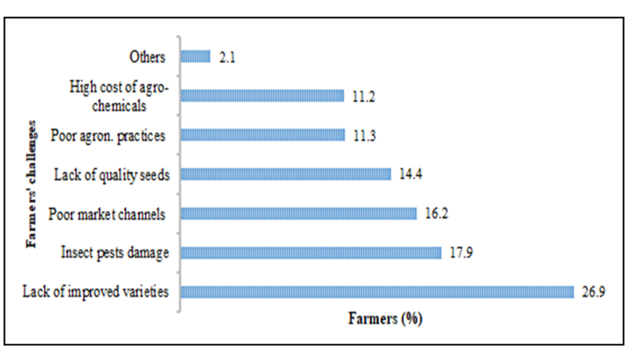

Figure 5: Main challenges perceived by farmers in Lablab production in Tanzania ($\chi^2 = 10.079$; $p = 0.994$, df = 24).

3.2.6 Some climatic trends in Lablab production areas

Figure 6(a–e) shows that the production of Lablab was taking place in areas with dry climatic conditions. June–August was the driest period across the Lablab agro-ecological production zones for a consecutive period of 5 years (2014–2018).

4 Discussion

4.1 Lablab: production trends and seed color diversity

Lablab grows in different agro-ecological zones as noted in the present study (Table 1 and Figure 2). The availability of Lablab in the diverse range of agro-ecological conditions complies with its great genetic diversity [28] (seed color diversity in Figure 1 as reference) and adaptation over a wide range of climatic and environmental conditions [29]. Such characteristics attracted farmers to utilize this crop for multifarious uses. It was noticed that Lablab is considered as a traditional crop and was grown mainly by smallholder farmers [30]. The typical scenario for this characteristic is a small level of production with a range of local names assigned to the landraces (Table 1).

A decrease in Lablab production and loss of its popularity in Africa was reported by Maass et al. [4] and Forsythe [23] in the early 1900s after the introduction of *phaseolus* beans. Unfortunately, declined production of Lablab in Africa took place in almost all except in few areas. These few areas involved the Kikuyu land from central Kenya and northern regions of Tanzania where demand for Lablab crop from Kenya supported an active production [6,33]. The Lablab demand for the market in Kenya had an influence on seed color diversity in Tanzania (Figures 1 and 2). Black seeds were the market's choice for Lablab in Kenya [32], and their demand triggered their higher production in northern Tanzania. Black seeded cultivars became the most dominant cultivars in the northern regions of Tanzania (Table 1 and Figure 2) and this lowered the seed color diversity in these regions. The rest of the country was left with few farmers producing their own cultivars for subsistence farming and this maintained the

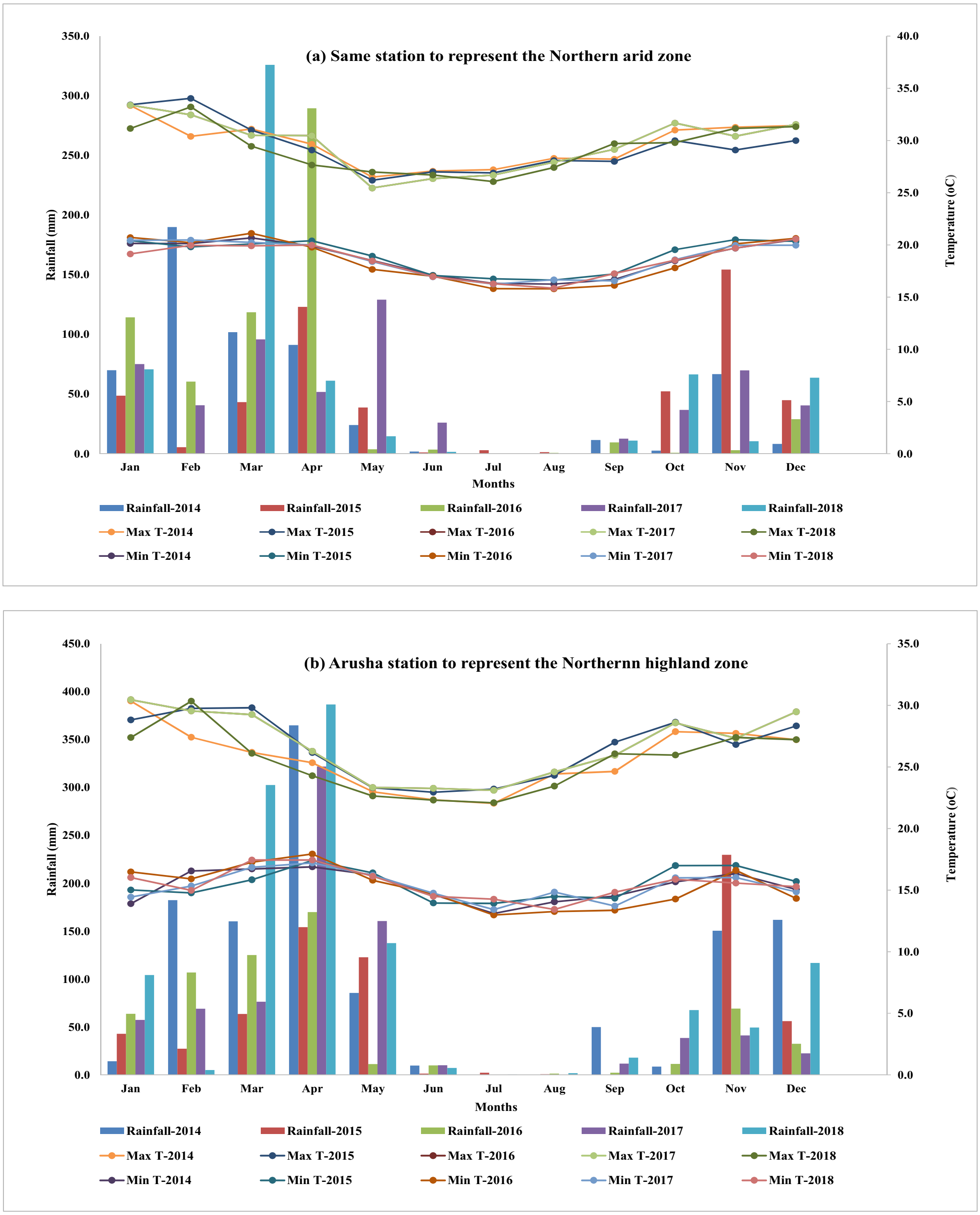

Figure 6: (a) Weather data showing the trends in rainfall (mm) and maximum and minimum temperatures (°C) in the Northern arid zone for a period of 5 years (2014–2018) as represented from Same station; June–August were established as the driest months. (b) Weather data showing the trends in rainfall (mm) and maximum and minimum temperatures (°C) in the Northern highland zone for a period of 5 years (2014–2018) as represented from Arusha station; June–August were established as the driest months. (c) Weather data showing the trends in rainfall (mm) and maximum and minimum temperatures (°C) in the Central zone for a period of 5 years (2014–2018) as represented from Dodoma station; June–October were established as the driest months. (d) Weather data showing the trends in rainfall (mm), maximum and minimum temperatures (°C) in the Eastern zone for a period of 5 years (2014–2018) as represented from Kilosa station; Mid-June–September were established as the driest months. (e) Weather data showing the trends in rainfall (mm) and maximum and minimum temperatures (°C) in the Coastal zone for a period of 5 years (2014–2018) as represented from Handeni station; June–August were established as the driest months.

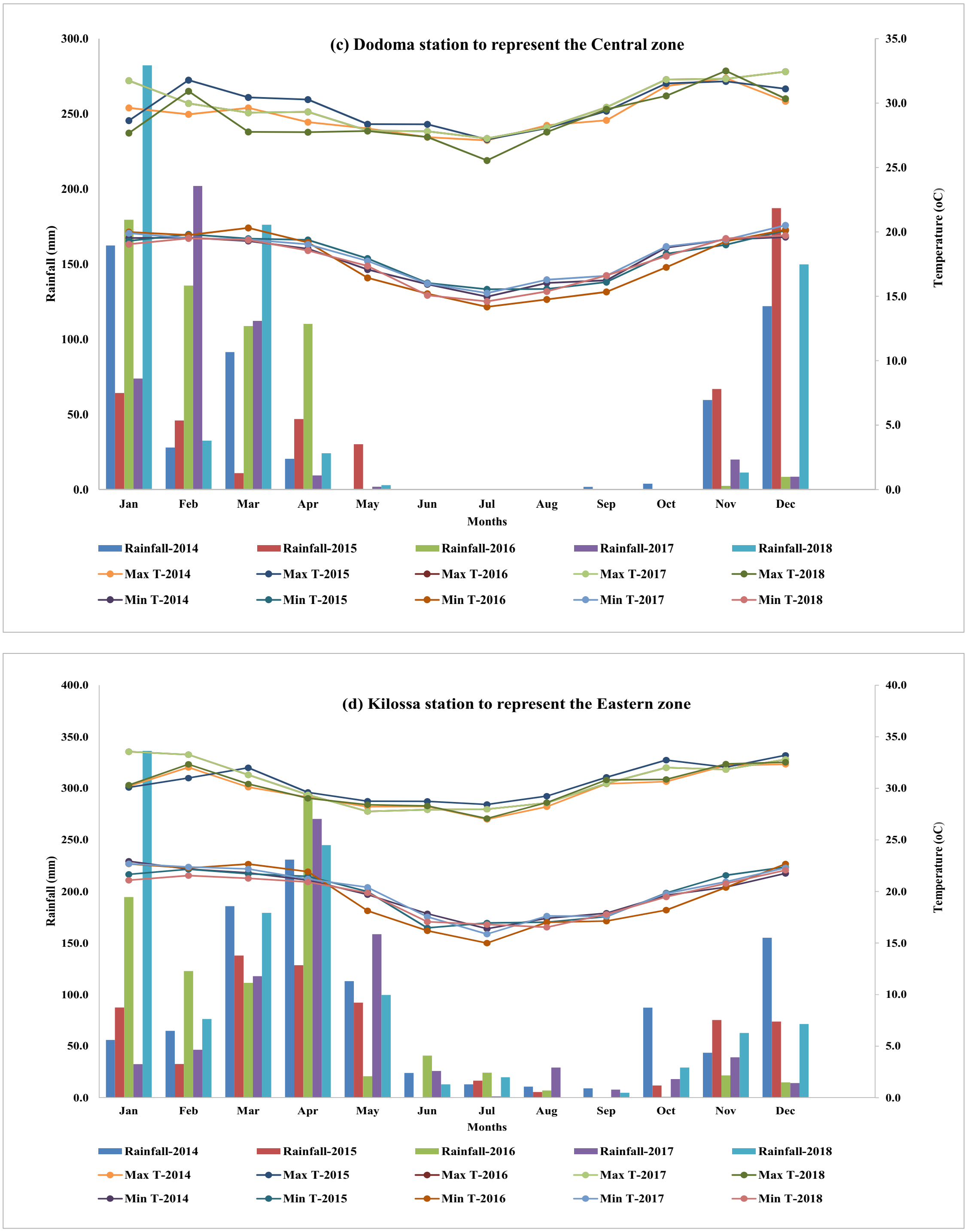

Figure 6: (*Continued*)

seed color diversity high in this part of the country (Figure 2; Table 4(i)). To optimize the market opportunity of Lablab in Kenya, the strong market channels were more oriented to the northern zones than to the rest of the country (Table 5(v)) [21,23].

A decrease in Lablab production in many areas of the country and the focus of many farmers on black seeded cultivars in northern regions contributed to a loss of Lablab genetic diversity. There was little institutional and organizational support to develop Lablab production during colonial rule and soon after independence as noted in this study (Table 2). Since 2000s, Lablab production in Tanzania started to expand especially in the northern regions as influenced by market demand from

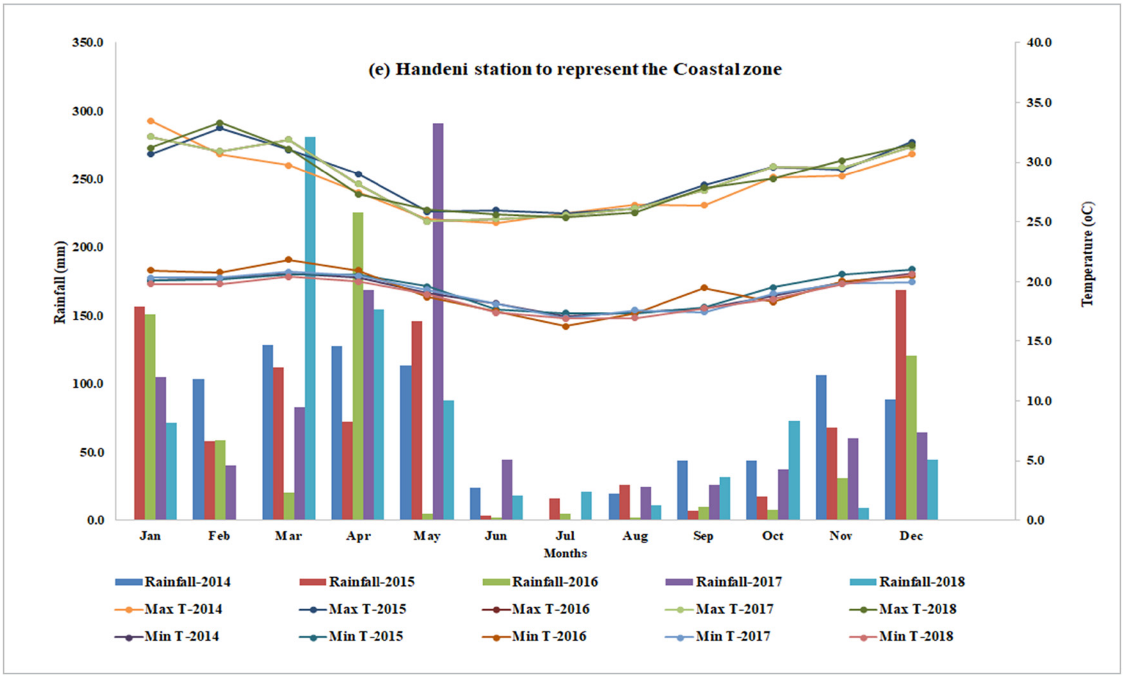

Figure 6: (*Continued*)

Kenya. Miller et al. [6] reported an increase of about 20,000 ha of land with 8,000 tons of grains in the country. However, this expansion of Lablab production in the country could not move together with research improvement of this crop. There was still lack of infrastructure for Lablab research in the country. Lack of fund to support Lablab research activities was another obstacle in the development of this crop. The advanced research for this crop is only available in Asia especially in India and Bangladesh where its utilization is higher compared with Africa. Their research findings could demonstrate a future perspective of this crop in other countries especially in Africa where genetic diversity studies and genomic improvement of Lablab are still down.

Seed color diversity is the basic approach for genetic characterization of the crops. However, color itself is not sufficient to approve the diversity of the crop. Former studies on genetic diversity of Lablab core collections [33] showed distinct results among the East African accessions [21]. However, the molecular diversity of Kenyan Lablab collections was revealed to be narrow [34] and moderate [35] when compared with the Lablab collections from other African countries. There is still limited information on molecular characterization for Lablab genetic resources from other Lablab production countries in Africa such as Tanzania.

4.2 Farming systems in Lablab production

Lablab is mainly produced as a sole crop or mixed with other crops. It is grown as intercrop with maize, sorghum, millet, castor, and groundnuts [36]. Minor farming systems in Lablab production include rotation, relaying cropping, and home gardening [37]. In the current study (Figure 4), sole cropping was found more in very dry areas or areas with market potential especially in the northern zones. In almost all surveyed areas, farmers were intercropping Lablab with other crops only with minor variations. In northern and coastal regions, Lablab was mainly intercropped with maize, while in the central zone, farmers preferred to intercrop Lablab with sorghum or pearl millet. Few farmers were practicing crop rotation with Lablab. In Magugu village in Babati district, Lablab was grown after paddy to utilize moisture left out after harvest. In lower lands of the northern highland zone e.g., Bwawani village in Arumeru district, farmers were practicing relaying cropping by growing Lablab after maize. Some farmers in the central zone were growing Lablab in their farm houses. The trees available in their farms were used to support the Lablab crop. Similarly, Lablab was also grown as a garden crop in the northern highland zone where it was mixed with banana. Some of these farming systems in Lablab production were previously reported in several areas of the country [6,23,38]. Such presence of Lablab crop in farmers' production systems has been providing a great opportunity to improve conservation agriculture through enhanced soil nitrogen and organic residues [39,40]. Mureithi et al. [41] described Lablab as a cover crop with a high ability to manage soil fertility. On top of that, Lablab intercropping systems improve the diversity of crops, household dietary intake, and cash income among farmers [42,43].

4.3 Various uses and practices in Lablab production

Lablab has also a range of benefits to farmers in Tanzania (Table 4). It serves for food, income, and crop production sustainability especially in dry areas (Figure 3). In the present study, Lablab was reported among farmers as their reliable source of food and income during hard times of drought stress. However, Lablab was less preferred for consumption in Tanzania compared to Kenya. Even their cultivars' choices for consumption were quite different. As discovered in the present study (Table 4), white colored seeds were highly preferred for consumption in the country similar to farmers in Asia [44]. The preference of Lablab among consumers in the country involved seeds mainly when dry and by few when grains are still greenish. Very few consumers reported the use of young leaves as vegetables. D'Alessandro and Molina [38] reported the use of Lablab seeds and leaves as culinary ingredients in Tanzania. Other parts of plants such as immature (tender) pods were not described by farmers as their food material in the country. This is different from Kenya and India where consumption of Lablab involves other parts of the crop [4]. Lablab was also a part of food material during traditional ceremonies. For instance, "*Kishumba*" and "*roshoro*" were farmers' traditional foods in Arusha and Kilimanjaro regions that incorporated Lablab dry grains, maize, and milk. These kinds of foods was reported by farmers to offer many health benefits including regulation of blood pressure, improvement in body immunity, increase in energy, and removal of body toxins.

Lablab is also used as animal feed. The forage from Lablab usually remains fresh with high quality even after dry season to improve the digestibility [45]. Forages from farmers' common crops such as maize stover, banana leaves, and wheat straw were reported by Nord et al. [7] as low-quality material for livestock. Aganga and Tshwenyane [29] reported high-quality livestock products (milk and meat) when fed on Lablab. However, little use of Lablab for human consumption and livestock feeding among farmers in this study was partially due to a lack of improved varieties and limited farmers' knowledge on utilization. Anti-nutritional factors and unpleasant organoleptic properties also influence the nutritional quality and cooking time of Lablab seeds [11,43]. The production of Lablab among local farmers in Tanzania does not consider many inputs at the beginning. This crop thrives well in varieties of soils in a pH range of 5–7.5 [40]; however, farmers in Tanzania have their own soil choices to grow Lablab. Loamy-centered soil with well-drained humus was reported by farmers in this study as their best soil in Lablab production. This preferred type of soil for Lablab production was known as "*ngusero*" in the northern highland zone. Despite a range of soils in farmers' fields, none of the farmers declared seed treatment nor the use of synthetic fertilizers in Lablab production. However, they sprayed pesticides to control insect pests. The farmers usually harvested thrice and the remaining materials were utilized for livestock feeding and as organic residues. They stored their harvest mainly for market, seeds, and a little bit for food reserve. Usually, short periods of storage targeted the market especially in areas with high market channels, while longer periods meant for seeds. Most of their storage tools were polythene bugs famously known as "viroba," market bags, barrels, and baskets. Minor storage involved sisal bags, gunny bags, clay pots, and plastic bottles which farmers used for seed storage, especially in the central zone. Improvement in these storage techniques so that they accommodate farmers' harvest from a wide range of growing and harvest seasons (Table 5(ii) and (iii)) could also contribute to the improvement in Lablab production in the country.

This is because, Lablab is an East African origin crop [47,48] with a long history of production in the region [31,49], both history and marketing systems have been influencing farmers' experience, knowledge, and occupation in production (Table 3) to enhance food security and income generation among the community members. Therefore, socio-economic and demographic factors have a substantial contribution to the crop improvement and sustainability as they touch farmers' life [46]. Sex or gender is a sensitive issue in production of legume such as Lablab (Table 3) as it creates production motives. Women normally tend to focus more on subsistence farming rather than men who concentrate mostly on commercial production [50].

4.4 Farmers' main challenges in Lablab production

Farmers face several challenges in Lablab production as noted in the present study (Figure 5). Low yield has been the most leading challenge in Lablab production in Tanzania. The farmers in many surveyed areas were able to harvest only 4–7 bags (100 kg per bag) of Lablab grains per hectare. This is a very low yield compared to the improved varieties that produce 1.5–2.0 t ha^{-1} and 2.5–5.0 t ha^{-1} of dry seeds, or green pods, respectively [7,8]. Lablab improved varieties can also produce approximately 6–13 t ha^{-1} of dry matter [51]. This production in Lablab differs from the yield obtained among improved varieties in common bean (0.88 t ha^{-1}) and cowpeas (1.3–1.5 t ha^{-1}) [52,53].

Insect pests' damage especially at flowering and podding stages was mentioned by farmers as another serious challenge in Lablab production in the country. The common insect pests found in farmers' fields included aphids, leaf miners, caterpillars, pod and stem borers, stink bugs, and grasshoppers. Bruchid was the most severe pest in storage. The challenge of insect pest in Lablab production was reported by Miller et al. [6] in northern Tanzania. Similarly, other scientists [9,10] reported this challenge in other Lablab growing countries. However, Lablab showed less susceptibility to disease infestations.

Field evaluation of Lablab potential genotypes for high yield in Tanzania has already taken place in the northern zone [7]. There was ongoing program to release Lablab improved varieties for commercial use in Tanzania during this study. So far it is only Kenya among African countries that has released its Lablab commercial varieties i.e., Eldoret Kirkhouse Trust (Eldo-KT) Black 1 and 2, Eldo-KT Maridadi, and Eldo-KT cream [54,55]. The reason behind few Lablab commercial varieties in Africa is the little focus on breeding and genetic and genomic improvement of Lablab among African research institutions.

Due to the poor economic value of Lablab, as reflected in commercial production in some areas in Africa, its seed supply has not been as strong as other major legumes such as common beans and cowpeas. This is because Lablab falls in small-scale production mostly depending on local landraces. These landraces are poor in yield and take more time to harvest as they are indeterminate or semi-determinate in nature. Under this umbrella, Lablab production in Tanzania had poor market channels. The sole big market for Lablab grains from Tanzania is found in Kenya where the price fluctuates depending on its demand in Kenya. When the demand is getting saturated, the price of the crop usually falls substantially to influence the majority of the farmers in northern Tanzania [6,23]. However, no study has been done to conceptualize the amount of the crop produced and transported to Kenya especially during such scenarios of shifting in crop demand. This information is very crucial in opening up more marketing channels in other countries. Moreover, processing the grains into other products such as biscuits would add the value of the crop to improve new market links in other sources.

5 Conclusion and recommendations

Lablab landraces cultivation, farming systems, farmers' uses and practices, and some climatic trends were assessed across five agro-ecological production zones of Tanzania. The study revealed a wide cultivation and distribution of Lablab landraces across the zones with various production trends. The trends were mainly influenced by the market demand for Lablab in Kenya and its role in conservation agriculture. Further, the assessment found out that Lablab was mainly grown for marketing, conservation agriculture, and soil fertility improvement. To achieve their preferences, farmers owned various farming systems and production practices and yet were facing many challenges mostly unavailability of improved varieties, insect pests' damage, and poor market channels with a sole big market from Kenya. It was also determined that production of Lablab was taking place in dry areas with June–August established as the driest period across the zones. The effort is therefore required to develop high-yielding and drought-tolerant Lablab varieties while enhancing seed quality, farmers' knowledge, and conservation of genetic resources. There should also be an effort to enhance value addition to the harvested grains while diversifying their market channels to other countries.

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