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Towards food nutrition improvement: Assessment of Farmers' knowledge, perceptions and access to provitamin A-rich Maize in Tanzania

Selly D. Msungu*[1,2], Arnold A. Mushongi[3], Pavithravani B. Venkataramana[1], Ernest R. Mbega[1]

[1]*School of Life Sciences and Bioengineering (LiSBE), The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania*

[2]*Mwalimu Julius K. Nyerere University of Agriculture and Technology, Mara, Tanzania*

[3]*Tanzania Agricultural Research Institute (TARI), Ilonga Centre, Morogoro, Tanzania*

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Abstract

Maize is an important staple food and income-generating crop in most regions of Tanzania. The crop provides calories and other important micronutrients including vitamin A. This study was conducted in 3 maize growing zones of Tanzania to assess farmers' knowledge and perception on provitamin A-rich maize (proVAM). Purposive sampling technique was employed involving 366 respondents. The study observed that 55.2% of respondents were unaware of proVAM and mixed perceptions about proVAM were observed, where 38.5% of respondent perceived proVAM as livestock feed, 37.5% perceived proVAM as good nutritious food for children and adults, 18% of respondent perceived proVAM as food for low resource individuals, and only 7% of respondent perceived proVAM as suitable for HIV victims. The results show that growing proVAM, proVAM consumption, years of growing local varieties, and household size were major factors influencing farmers' knowledge of proVAM. The study found lack of awareness and low adoption of proVAM were exacerbated by seed unavailability (53%), lack of knowledge on provitamin A maize (23%), high seed price (21%), and limited extension services (3%). The expression of interest by the majority of farmers in planting such proVAM guarantees its future production and use proVAM. The study findings conclude that farmers have a different understanding and mixed perceptions of proVAM. Thus, deliberate strategies are needed to ensure seed availability, increased proVAM acreage and increased proVAM consumption to reduce vitamin A deficiency prevalence among vulnerable groups.

* **Corresponding Author:** Selly D. Msungu ✉ msungus@nm-aist.ac.tz

Introduction

Maize (*Zea mays* L.) is among the principal cereal crops serving for food security and a source of income in most developing countries. Maize is the third most important cereal grown after wheat and rice in terms of production and consumption (Santpoort, 2020). About 70% of maize produced in developed countries is used as livestock feed in addition to industrial use, while two-thirds of maize produced in Sub-Saharan Africa (SSA) is used for human consumption (Ranum *et al.*, 2014). In SSA, maize is cultivated on more than 33 million hectares (Yarnell, 2008), where South Africa, Nigeria, Ethiopia, Tanzania, Malawi, Kenya, Zambia, and Zimbabwe are leading maize producers in Africa (FAOSTAT, 2021). According to FAOSTAT (2021), in 2019, Tanzania produced 5,652 metric tons of maize and the annual consumption was 128 kilograms per person. Principally, maize crop is grown in all agro-ecological zones (AEZ) of Tanzania, however, Southern highlands (SHZ) (45%), Lake Victoria zone (LZ) (30%), and the Northern highlands zone (NHZ) (10%) are main producing zones with an average production yield of 1.6 MT/ha (Suleiman, 2018). The reported low yield has been attributed to a number of factors such as inadequate availability of improved seeds, lack of awareness and access to improved varieties, pests and diseases, drought stress, and soil fertility decline in most farming areas (Khan, 2019; Mng'ong'o *et al.*, 2021). All of this affects maize productivity and allow only a few varieties particularly white maize to be produced.

Maize is consumed in various food forms where most common is stiff porridge (commonly known as Ugali in East Africa). The other food prepared from maize includes 'makande' which is a boiled mixture of maize and legume seeds i.e., cowpeas, beans, and pigeon peas. In addition, roasted and cooked fresh maize is another consumption practice. The dried orange maize has been used to prepare popcorns, a popular type of maize snack (Oniang *et al.*, 2003; Ekpa *et al.*, 2018; Titcomb *et al.*, 2020).

Nutritionally, common maize has a high content of starch, protein, and oil, however, the crop is deficient in micronutrients such as vitamin A especially white maize (Atta, 2016). Thus, communities that solely depend on white maize as the main meal are at high risk of suffering from vitamin A deficiency. Vitamin A deficiency (VAD) is the result of insufficient intake of vitamin A-rich diets (Olson, 1987; Palacios-Rojas *et al.*, 2020).

Vitamin A is an essential micronutrient for human vision, maintenance of epithelial cells, cellular differentiation, growth, reproduction, bone development, and modulation of the immune system (Bailey *et al.*, 2015; Sinbad *et al.*, 2019). Vitamin A can be obtained from animals (retinol) such as liver, fish, dairy products, and poultry products or plants (provitamin A) sources such as roots, leaves, flowers, shoots, fruit, and seeds of various plants (Fraser & Bramley, 2004; Maqbool *et al.*, 2018; Wurtzel *et al.*, 2012).

Vitamin A deficiency remains a significant health problem in Tanzania like other countries in the SSA region, and its prevalence has been rising as a result of reliance on maize-based diets with low provitamin A concentration. According to Ndau *et al.* (2016), VAD affects 33.5% of children aged 6 to 59 months and 39.5% of women of reproductive age. This is a worrying scenario that requires special attention to control the impacts of VAD (Oikesh *et al.*, 2003; Harika *et al.*, 2017).

The health complications associated with VAD range from mild (e.g. night blindness) to severe symptoms leading to total blindness, cornea scarring, growth retardation, anaemia, and a weakened immune system, making the patient more susceptible to contagious diseases (Fragoso *et al.*, 2012; Harjes *et al.*, 2008). Tanzania's government has used a variety of strategies to control VAD, these include vitamin A supplementation, food fortification, and diet diversification. Despite the efforts made to fight the prevalence of VAD, the problem has been increasing, particularly in rural areas where food diversification and other interventions have been difficult to execute. Several studies have emphasized that VAD can easily be prevented through the consumption of proVAM (Biljon & Labuschagne, 2021; Ekpa *et al.*, 2018). The problem is exacerbated by the limited ability of most households to afford alternative vitamin A-rich foods, primarily from animal sources.

The study by Wilson and Lewis (2015) reports that maize is a staple diet for more than 65% of Tanzanians, therefore, using provitamin A-rich maize, also known as biofortified maize, is a cost-effective way to prevent VAD (Low *et al.*, 2000; Bai *et al.*, 2011). Meru Agro Seed Company has released two biofortified provitamin A-rich maize varieties in Tanzania: Meru VAH 517 and Meru VAH 519, however, the consumption of this nutritious orange maize and other yellow maize has received low acceptance and negative perceptions by many Tanzanians. In a number of developing countries, knowledge, perceptions, awareness, and access to provitamin A-rich maize have been reported to be among the important social-cultural factors that influence the adoption and consumption of orange maize (Afzal *et al.*, 2017; Jenkins *et al.*, 2018; Khumalo *et al.*, 2011). Understanding these social-cultural factors that influence the adoption and consumption of orange maize is of paramount importance. However, no studies have been carried out in Tanzania to understand knowledge, perceptions, awareness, and access to proVAM in relation to VAD control. Therefore, this study was conducted to assess farmers' knowledge, perceptions, and access to proVAM in Tanzania. The information gathered from this study is valuable in raising awareness about proVAM intake by addressing the knowledge gap among maize value chain operators. Moreover, the findings will aid researchers in developing and increasing proVAM availability varieties in Tanzania for enhanced, food nutrition and security for improved maize consumers' health.

Materials and methods

Description of the study area

The study was conducted in three major maize-producing agro-ecological zones (AEZ) of Tanzania i.e., the Southern highlands zone (SHZ), Northern highlands zone (NHZ) and Eastern zone (EZ) (Fig. 1). The study area has two predominant rainfall regimes: unimodal and bimodal rainfall, where SHZ has a unimodal regime from November to late April, whilst the EZ and NHZ have bimodal rainfall pattern, with two rainy seasons, one being a short rainy season 'Vuli' from early October to December, and the second longer rainy season 'Masika' from March to May. The sampled areas have an altitude ranging from 306 to 1935 meters above sea level (masl) with cool and hot months, with a minimum to a maximum of 11.8 to 29.5^{o}C respectively.

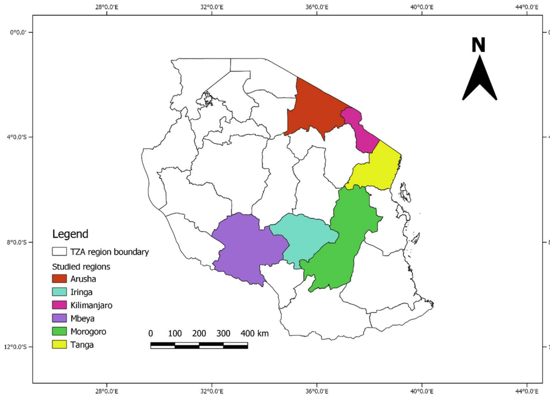

Fig. 1. The map showing six regions from three agro-ecological zones of Tanzania surveyed during the 2020/2021 cropping season.

Sampling procedure and data collection

A purposive sampling technique was used to determine the sample population of maize farmers. In each region, one district that ranks high in maize production records among maize growing districts was selected. From each district; three wards based on high maize production records were selected, and three villages per ward with high maize production records were selected. In each village, with the help of village agricultural field officers (VAFOs), active maize farmers were randomly selected for interview. Based on the Cochran formula; N = [Z^2 (p) (1 -p)/C^2]; where Z = 1.96, P=0.5% (picking a choice of response), C = confidence interval (0.95) (Bartlett *et al.*, 2001; Israel, 2003) were used to calculated the number of farmers to be involved in this study. Where, 366 farmers from six districts in three zones (SHZ, NHZ, and EZ) were randomly selected and involved in this study interview. The PRA tools i.e., key informant (KI) and semi-structured questionnaires (SSQs) (see supplementary material S1) were used to get farmers' information on demographic characteristics as well as debriefing questions on knowledge, perceptions, and access to provitamin A-rich maize. Before the official survey was conducted, the questionnaire was pretested for soundness and incorporation of important missing variables.

Where deemed necessary, the pretested questionnaire was modified to capture all the important information. Trained enumerators from the host wards/villages were used to assist in questionnaire administration. The study was conducted from January to June 2020 to coincide with planting dates in most areas. The KI involved the district, ward and village agricultural extension officers, research scientists, and the local government authorities from ward to suburb levels, non-governmental organizations (NGOs) officers and agro-dealers in the respective area of study. The discussion with these groups was supplemented by information from questionnaires. Before the commencement of the study, consent of farmers to participate in the study was obtained as the enumerator had to read and interpreted the designed consent form and requested each farmer to provide oral informed consent to participate in the interview. This study was given ethical approval by Tanzania Government through the Ministry of Local Government Authority with permit reference number Ref.No.FA.255/265/01/05 for Mbeya and Iringa regions and Ref.No.DA.228/258/04/213 for Morogoro, Tanga and Kilimanjaro region. From the interviewees, information collected includes farmers' socio-demographic characteristics, viz.; sex, age, marital status, household heading status, household size, level of education, principal occupation, and farming experience in maize production. Awareness of the importance of improved maize varieties, maize preferences by colour, and provitamin A-rich maize production and consumption data were also collected.

Statistical data analysis

The collected data were organized, coded, and analyzed using IBM SPSS 21.0 (New York, USA) (at a 5% level of significance). Descriptive statistics, frequencies, and percentages were computed for socio-demographic data which show the distribution and fragmentation of respondents and their characters in the study area. Furthermore, descriptive statistics were conducted to describe the knowledge perceptions and access of farmers on provitamin A maize (proVAM). Then a one-way analysis of variance (ANOVA) was conducted through SPSS to determine significant differences between different socio-demographic characteristics (using their mean percentages), knowledge, perceptions, and access attribute to provitamin A maize. To determine the mean difference among age groups, zones, regions and districts to the studied parameters, the Tukey HSD post hoc test were conducted at a 5% level of significance. Furthermore, the multinomial logistic regression was conducted to identify the interaction between the independent factor (knowledge and perception of provitamin A maize) against predictors, such as socio-demographic factors like age, marital status, education level, gender, and household size. Lastly, Pearson's correlation among studied variables was also performed.

Results and discussion

Socio-demographic characteristics

The socio-demographic characteristics studied in this study included sex, status in the household, age, education level, marital status, primary occupation, and household size (Table 3). The study found that both men and women were involved in maize production, however, played different roles. Significant variation (P<0.05) in the number of males and females who participated in maize production was observed across zones. A high number of male farmers were observed in EZ (65.8%) and SHZ (53.05%). A large proportion of female interviewees were reported in the SHZ (46.65%). These results are in agreement with those of Ngailo *et al.* (2017) who previously reported more male farmers' participation in paddy rice farming in the Southern Highlands of Tanzania.

The age of farmers differed significantly (P<0.05) across the zones, where the highest proportion of farmers (42.4%) were aged between 37 to 47 years with few (6.3%) being above 59 years, and only 5.3% of farmers interviewed were youth aged 20-25 years (Table 1). The dominance of farmers aged 37 to 47 years implies that most farmers in maize production were energetic enough to provide the required labour force in maize production in the area. This study found that few respondents (5.3%) of young age (20 to 25 years) were being involved in maize farming, this is because this group (youth) have shifted to other quick income-earning occupations such as the production of horticultural crops and transportation sector mainly those using two or three-wheeled motorbikes or motorcycles commonly known as "boda boda" or "bajaji" respectively in Tanzania, betting, and online marketing. Aged farmers have accrued experience and knowledge over experimentation and observations, thus older farmers are more or less likely to adopt proVAM varieties. They might find it challenging to leave the accustomed varieties for new, improved proVAM. Akudugu *et al.* (2012) found that older farmers may assess the newly brought varieties better than their younger counterparts.

The Education level among farmers varied significantly ($P<0.05$) among zones; farmers with formal and primary education were statistically different ($P<0.05$). The majority (73.5%) of farmers had attained primary education (Table 1). The results are in line with those reported by Udimal *et al.* (2017). The results imply that the farming community was literate enough that it would be easy for them to read, write, make the right decision, and even follow training on the importance of proVAM consumption. The education level affects the decision-making and willingness to join in innovation and technology.

The results revealed significant variation among farmers' occupations across zones ($P<0.05$). The majority of respondents (89.6%) were self-employed as a crop producers. The present results agree with those reported by Urassa (2015) who reported that a large number of farmers were employed in crop production. Other interviewees besides being farmers were also livestock keepers (7.1%), entrepreneurs (1.9%), and some were salary employees (1.4%). This implies that in the study area crop production was a major income-earning activity and if improved might influence the standard of living in the study area. Crop production employed more than 98.35% of farmers in the EZ, 96.65% in the SHZ, and 63.15% in the NHZ (Table 3). Cropping and livestock keeping, or mixed farming (2.55%) were practised mainly in the NHZ, this could be due to bimodal rainfall patterns received in the area.

A low number of farmers in crop production in NHZ was probably influenced by the participation of the farmers in other income-earning activities including livestock husbandry and tourism activities.

The majority of the EZ areas including Kilosa receive bimodal rainfall patterns from March to June ("Masika") and November to January ("vuli"). These good climatic conditions and fertile soil supports the production of several crops including maize, hence attracting more farmers to venture into maize production in this zone. Additionally, maize growers in the Kilosa district received training on the production and importance of provitamin A maize from different institutions including TARI-Ilonga and seed companies through demonstration plots ("shamba darasa") and farmer field schools (FFS) which have accelerated proVAM production. So, whatever strategies are implemented to improve the maize crop may have a more significant influence on people's livelihoods, food, and nutrition security at large.

The study found that farmers' experience in farming (Table 3) did not differ significantly ($P>0.05$) among zones. Farmers had experience in provitamin A-rich maize production that ranged from one to five years. The present study accords with that of Nyeko *et al.* (2004) and Negatu & Parikh (1999) who insisted on the importance of experience in influencing the knowledge and perception of farmers on the decision of growing new crop varieties. The farmer's decision to adopt a new proVAM variety depends on the awareness that farmers may have on that new variety acquired through experience (Akudugu *et al.*, 2012; Sánchez-Toledano *et al.*, 2018).

Maize production in Tanzania

Maize varieties, sources, production, and consumption

Maize in Tanzania is grown largely for food and small farmers prefer local/traditional varieties, open-pollinated varieties (OPVs), and other improved varieties which have lower input and management requirements. Where maize is grown for income generation, improved OPVs and hybrids are more preferred over local varieties. The results (Table 2 and 3) indicate that farmers grow both local and improved varieties (IMVs) to cater for their daily demands. Arumeru and Hai districts in the Northern zones recorded higher production of IMVs whereas lower utilization was reported in the EZ (Kilosa and Korogwe districts). The present results concur with those reported by Kathage *et al.* (2013) who concluded that in the north, hybrid seeds are highly utilized as compared to the east where there is low usage of IMVs. The differences in the adoption of IMVs between agro-ecological zones can be explained by differences in profitability and market availability of the product, as adoption is higher when the benefits are larger.

Table 1. Socio-demographic variables determined in the study area.

Demographic parameter		Agro-ecological zones under the study							
		Northern zone		Eastern zone		Southern zone		Overall Mean	P-value
		Arumeru (n=61)	Hai (n=65)	Kilosa (n=58)	Korogwe (n=62)	Kilolo (n=60)	Mbarali (n=60)		
		(%)	(%)	(%)	(%)	(%)	(%)	(%)	
Sex	Male	54.1	56.9	65.5	66.1	46.7	60	58.2**	0.003
	Female	45.9	43.1	34.5	33.9	53.3	40	41.8**	0.003
Age (years)	20 - 25	4.9	4.6	13.8	1.6	5	1.7	5.3**	0.001
	26 - 36	18	15.4	27.6	19.4	18.3	31.7	21.7	0.993
	37 - 47	47.5	52.3	24.1	38.7	46.7	45	42.4**	0.005
	48 - 58	24.6	24.6	24.1	30.6	25	16.7	24.3*	0.021
	> 59	4.9	3.1	10.3	9.7	5	5	6.3	0.766
Education	Informal	16.4	4.6	6.9	12.9	10	1.7	8.75***	< .001
	Primary	65.6	76.9	79.3	72.6	68.3	78.3	73.5***	< .001
	Secondary	14.8	13.8	12.1	14.5	16.7	16.7	14.8	0.085
	University	3.3	4.6	1.7	0	5	3.3	3	0.104
Occupation	Crop prod.	34	92.3	98.3	98.4	93.3	100	86.1	0.986
	Employee	1	1.5	0	1.6	3.3	0	1.2	1
	Entrepreneur	2	3.1	1.7	0	3.3	0	1.7	1
	Mixed farming	24	3.1	0	0	0	0	4.5	0.986
Head of HH	Yeas head	52.5	60	67.2	66.1	46.7	60	58.75**	0.003
	No head	47.5	40	32.8	33.9	53.3	40	41.25**	0.003
Household size	2-Jan	4.9	6.2	6.9	11.3	16.7	10	9.3	0.992
	4-Mar	27.9	38.5	41.4	25.8	60	51.7	40.9	0.996
	6-May	44.3	32.3	29.3	32.3	18.3	33.3	31.6	0.993
	> 6	23	23.1	22.4	30.6	5	5	18.2	1
Farming experience (years)	2-Jan	1.6	6.2	0	0	0	0	1.3	0.059
	5-Mar	3.3	6.2	0	0	0	0	1	0.997
	> 5	37.7	18.5	60.3	64.5	83.3	45	25.8	0.965

Note: The mean values with asterisk and bold are statistically significant different at * <0.05, ** <0.01 and *** <0.001.

The present study found that essentially two types of maize produced in Tanzania, are yellow and white maize obtained from various sources. The study (Table 2) found that majority of farmers obtain planting materials (seeds) from agro-dealers (65.8%) for the case of improved one. And for the case of local cultivars, they got from their neighbours (18.8%) through diffusion, as well as farmers' own served seed (15.4%). The present results are in line with those reported by Sánchez-Toledano *et al.* (2018) when studying the use of improved maize varieties and the preference of farmers to locally adapted maize cultivars. The interviewees testified that in addition to growing the improved varieties due to their high yield, they also prefer their local or traditional varieties. The preference for traditional cultivars shown by farmers has been related to their good taste, tolerance to storage pests, and better adaptation to the environmental stresses i.e., nutrients and moisture requirements. Additionally, local cultivars (Table 2) were cheap, easily accessible, and were stable to climatic inconsistency. The findings from this study correspond with those reported by Eakin *et al.* (2014). The study found different types of local maize (pigmented or non-pigmented) grown by respondents in the study area (Table 3).

Table 2. The price, type, and source of maize seed grown in surveyed agro-ecological zones.

Price per kg of seed (TZS)	Frequency	Percent (%)	Type of maize	Source of seed
500-1000	67	18.8	Local white maize	Neighbour
1500-2000	56	15.4	Local yellow maize	Farmers
2500-5000	212	57.9	Improved white	Dealers
> 8000	29	7.9	Improved yellow	Dealers
Total	364	100.0		

TZS-Tanzanian shillings Source: Own survey data

Table 3. Description of local maize grown in each district in three agro-ecological zones of Tanzania.

District	Type of maize grown & number of farmers in brackets	Local maize varieties grown	Percentage (%)
Arumeru	White maize (43)	Kilima, Local white	76.8
	Yellow/orange maize (13)	Local yellow	23.2
Hai	White maize (46)	Stuka, Local white	82.1
	Yellow/orange maize (10)	Local yellow	17.9
Kilosa	White maize (37)	Local white, Kiguruwe, and Staha Mzigua, Sina	84.1
	Yellow/orange maize (7)	Local yellow	15.9
Korogwe	White maize (35)	Mzigua, Sina, Staha, Local white	74.5
	Yellow/orange maize (12)	Local yellow,	25.5
Kilolo	White maize (39)	Kimkoka, Nzimbu, Nchunju, Staha and Mchakamchaka	84.8
	Yellow/orange maize (7)	Bwanaromba, Yanga, Ganjano	15.2
Mbarali	White maize (36)	Chunya, Kito, Kwangalambi and Staha	87.8
	Yellow/orange maize (5)	Local yellow, Makaya, Malewa & Penda	12.2

Access of farmers to provitamin A-rich maize seed

The results (Table 5) found two commercial proVAM varieties were grown in the study area, i.e., Meru VAH 517 and Meru VAH 519. These varieties were developed by Meru Agro Seed Company, an in-country seed company. Despite the availability of these proVAM varieties since 2016, it has been observed that few farmers access and grow these varieties (Gethi and Maru, 2017).

The Northern zone regions had more proVAM seed in the market than other zones hence it was more likely to be easily accessed by the farmers during the planting period despite its high price. The study further observed other improved yellow maize varieties (CP 201 and CP 808) from Charoen Pokphand Seed Company were also grown by farmers in surveyed areas (Mulongo *et al.*, 2017; CIMMYT, 2018; Dalberg, 2019).

The CP varieties also are the most grown in the study area as compared to other proVAM. Although the CP varieties (Table 4) have been reported in many parts of the study area. Several researchers have shown doubt on the level of provitamin A in CP maize to meet the VA human requirements, henceforth, needs to be characterized.

The inadequate and timely availability of seeds in the study area is a leading cause of low production of proVAM rich maize in the area which measure has to be taken by respective stakeholders to address these shortcomings (Table 5).

Easy access to improved proVA seeds increases the chance of willingness to adopt and use this maize. Generally, proVA varieties from both companies were not available in agro-dealer shops during the growing season. The main maize-producing zone, the southern highlands zone (SHZ) was the lagging zone in proVA seed availability. The access to planting materials plays important role in farmers' decision to grow the proVAM varieties and as they grow they are more likely to consume them.

Table 4. Different maize varieties and cultivars grown by farmers in the study area.

Type of maize	Arumeru	Hai	Kilosa	Korogwe	Kilolo	Mbarali
Local	19.7%	21.5%	39.7%	32.3%	35.0%	31.7%
Improved one*	62.3%	69.2%	44.8%	43.5%	45.0%	60.0%
Both	18.0%	9.3%	15.5%	24.2%	20.0%	8.3%
Stuka		1	2	3		
Staha			9	19		2
TMV1			4			
Meru	1	6		12	1	4
DeKalb	17	10	1		26	
UH 6303						4
Pannar	4		4		9	
Seed Co	24	13	5	8	3	30
CP	8 (CP201)	11 (CP201)	20 (CP 201)	9 (CP 201)		1 (CP 808)
KSC	14 (H 614)					10 (H 628)
Meru VAH		VAH 517			VAH 519	VAH 517

*NB: in Tanzania farmers could not identify varieties by brand but by production companies, that's why most improved varieties have company names in their variety name.

In addition, the study found that 38.80% of the participants grew orange maize whereas 61.20% were reported to grow white maize (Table 6). These results concur with those reported by Zuma (2019) who found that few farmers in South Africa preferred yellow maize. The low number of farmers growing orange maize is linked to a lack of understanding of the importance of proVAM in preventing VAD, high seed costs, and lack of biofortified proVAM varieties affordable to resource-poor people. Growing orange maize indicates that farmers have recognized its importance of it. For users of local yellow maize, might make it more likely for them to be transformed from conventional/ordinary maize to proVAM varieties. The amount of proVA in the local maize needed to meet the recommended body vitamin A requirement, they have to be enhanced through a biofortification approach.

Table 5. Provitamin A-rich maize varieties and local yellow maize grown by farmers.

District	ProVAM Variety	Seed Company	ProVAM Growers	Percentage (%)	Area (ha)	Yellow maize growers	Percentage (%)	The area under cultivation (ha)
Arumeru	Meru VAH 517	Meru Seed Co	8	16.0	8.5	26	18.3	12.4
Hai	CP 201	Charoen Pokphand	11	22.0	10	29	20.4	16.4
Kilosa	CP 201	Charoen Pokphand	20	40.0	13.5	33	23.2	19.6
Korogwe	CP 201	Charoen Pokphand	9	18.0	4.5	22	15.5	9.6
Kilolo	Meru VAH 519	Meru Seed Co	1	2.0	2	19	13.4	7.3
Mbarali	CP 808	Charoen Pokphand	1	2.0	1.5	13	9.2	5.8
Total	4	2	50	100.0	40	142	100.0	71.1

Table 6. Different types of yellow maize (local & improved) grown by farmers in the study area in 2020/2021 cropping season.

Yellow/Orange maize grown	Number of respondents (Frequency)	Percent (%)
CP 201 (Yellow)	40	10.9
CP 808 (Yellow)	1	0.3
Local yellow/orange maize	97	24.0
Meru VAH 517 (Orange)	8	2.2
Meru VAH 519 (Orange)	1	0.3
Not growing	224	61.2
Total	366	100.0

Results on production levels (Fig. 2), indicate that the majority of the respondents harvest between 1.5 (15 bags) and 2.0 tons of maize per ha, followed by those who produce 2.0 to 2.5t/ha and 2.5 to 3.0t/ha. Only a few respondents (Fig. 2) reported a yield of above 3.0t/ha under normal management practices.

These results are in line with the study by Stephen *et al.* (2014) who reported that the average yield of maize was less than 2t/ha among rural farmers. The reported low yield might be due to factors such as lack of awareness of improved seed and the high price of the improved seed. This agreed with previous work by Schroeder *et al.* (2013) who reported that the high cost of seeds was among the major obstacles to the adoption of hybrid maize production in SSA.

Yellow and white maize yields comparison

Respondents had varied views regarding the yield of yellow and white maize. The results (Table 7a) indicate that 61.5% of respondents were not aware of the yield difference between the two maize categories. Followed by 24.9% who reported high yield from yellow maize than white ones, the observation from farmers that yellow maize yields higher concur with the study of Maqbool *et al.* (2018) who confirmed that some yellow maize reported high yields. Other respondents (9%) stated that yellow and white maize produced similar yields. And 4% of the respondents reported that the yield from yellow maize is less compared to that from the white. High yield from white maize in comparison to that of yellow varieties was also reported by Nuss *et al.* (2012).

High yield is among the determinants for the choice of maize varieties to be cultivated, other important criteria include taste, personal preference, appearance, maturity period, resistance to pests as well as diseases, and drought stress tolerance. Aman (2021) insisted on breeding high-yielding proVA maize for increased adoption by farmers.

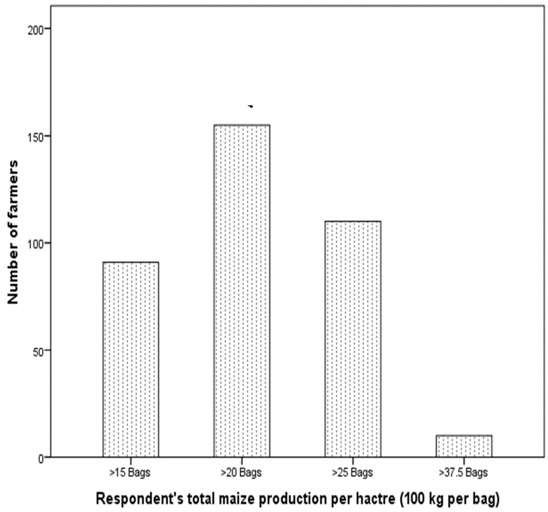

Fig. 2. Potential respondents' maize production levels per hectare in 2019/2020 cropping season.

Furthermore, the study determined the perception of farmers regarding the yield of provitamin A-rich maize (Table 7b). The study revealed that 34.4% of respondents perceived the yield of provitamin A-rich maize to be high. On the other hand, respondents (4%) stated that yields from yellow maize are intermediate. The study also found that the majority (60.7%) of respondents were not aware of the yield of provitamin A-rich maize. The findings of this study are consistent with those reported by Tripathi *et al.* (2021).

Table 7. The farmers' responses to three parameters related to yield and consumption of yellow or provitamin A-rich maize.

a	Comparison of yield from yellow and white maize		
	Response	Frequency	Percent (%)
	Yellow maize yields high to white	91	24.9
	Yellow and white maize produce a similar yield	33	9
	Yellow maize yields low	17	4.6
	Not aware	225	61.5
	Total	366	100.0
b	The yield of provitamin A maize per hectare		
	Response	Frequency	Percent
	High	126	34.4
	Medium	18	4.9
	Not aware	222	60.7
	Total	366	100.0
c	Consumption of yellow/provitamin A maize		
	Response	Frequency	Percent
	Yes	152	41.5
	No	214	58.5
	Total	366	100.0

Consumption of yellow/orange/provitamin a maize

This study observed that 41.3% of respondents consume orange maize. The study (Fig. 3) revealed that the Hai (NHZ) had a high consumption of orange maize followed by the Kilosa district (EZ), and the Mbarali district (SHZ). The observed findings are consistent with Muzhingi *et al.* (2008) and Chen *et al.* (2021). Awobusuyi *et al.* (2015) and De Groote and Kimenju, 2012 reported that farmers perceived yellow maize to taste good particularly when roasted and consumed as green maize. Zuma *et al.* (2019) claimed that smallholder farmers accepted proVA maize despite of its orange color. Studying consumers' acceptability of maize meals, Khumalo *et al.* (2011) also reported that consumers preferred yellow maize. The consumption of proVA maize may have been motivated by the realization of the importance of orange maize in intake for vitamin A provision, which is critical in fighting VAD. In contrast, most respondents (58.7%) reported not to consume yellow maize as they have preference for the white one. The current findings are in line with that of De Groote *et al.* (2011), who reported that yellow maize is not consumed by adult people in South Africa. The study by Ranum and Pe (2014), comments that being raised on white maize products is the reason why consumers oppose consumption of yellow maize.

Due to this preference for white maize, consumption of beta-carotene, a vitamin A precursor found in higher proportions in orange maize (proVA) is reduced. The situation is exacerbated by an insufficient understanding of the importance of orange maize on human health (Jenkins *et al.*, 2018). The findings suggest that there is a need to improve proVA maize acceptance, which can be accomplished by developing acceptable varieties and increasing nutrition education among consumers.

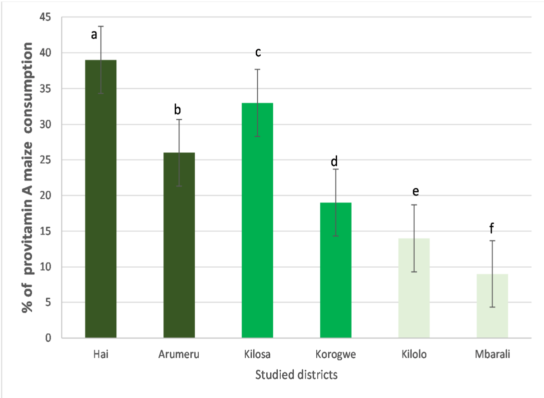

Fig. 3. The provitamin A-rich maize consumption in the study area during the 2020/2021cropping season (bar plots different letters are statistically significantly different at a 5% level of significance (P<0.05).

Farmers' awareness of provitamin A maize

In this study, it was observed that 55.2% of respondents polled had never heard of proVA maize. The current findings are in line with those reported by Oteh *et al.* (2020) and Okello *et al.* (2017), who found that farmers lacked awareness of biofortified cassava and orange-fleshed sweet potato (OFSP) resulting in very low consumption of these crops.

On the other hand, it was found that 44.5% of the interviewees in the study area were aware of proVA maize. Hai and Arumeru districts (Fig. 4) from Northern Zone reported having more understanding of proVA maize compared to other districts in the study area. According to Baudoin *et al.* (2013) and DeVries and Toenniessen (2001), it is critical to understand farmers' awareness on maize for incorporation on improved varieties and to their knowledge when developing a new one.

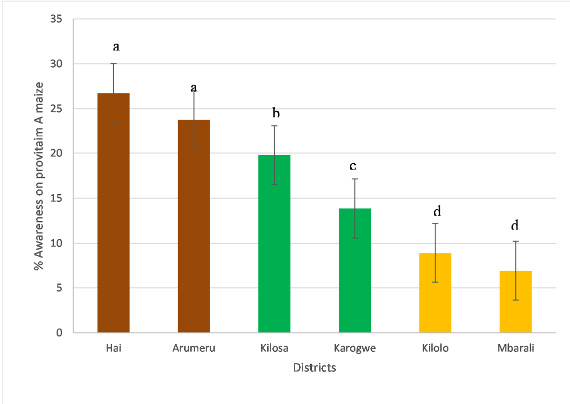

Fig. 4. Farmer's awareness of proVAM in study area during the 2020/2021 growing season (bar plots with different letters are statistically significantly different at a 5% level of significance (P<0.05).

Factors influencing farmers' understanding of provitamin A-rich maize

The results indicate that growing proVAM, proVAM consumption, number of years for growing local varieties, and household size were the major factors that positively and significantly influenced the farmers' knowledge regarding the proVA maize. A multinomial logistic regression model was used to determine the effects of sociodemographic factors on farmers' knowledge (Y) of proVA maize, as presented in equation 1.

$$\boldsymbol{Y} = -\mathbf{0.189} + \mathbf{0.66}\boldsymbol{GV} + \mathbf{0.218}\boldsymbol{VC} + \mathbf{0.141}\boldsymbol{YG} - \mathbf{0.052}\boldsymbol{HS}, (\boldsymbol{R}^2 = \mathbf{0.731}\ \boldsymbol{or}\ \mathbf{73.1}\%) \quad \ldots\ldots\ldots\ldots\ (1)$$

Where: GV is growing proVAM (%), VC is proVA consumption (%), YG is growing experience (years), HS is household size.

The R^2 value obtained was 73.1%; this shows that the descriptive variables can accurately predict the dependent variable and thus be able to explain farmers' knowledge on provitamin A maize.

Production of local yellow maize and provitamin A-rich maize

Farmers who had grown either yellow or proVA maize gained more experience and understanding of proVAM. The findings of this study correspond with those of Akinola & Nasa (2011), who found that as farmers were more knowledgeable of their varieties, they were more likely to use orange maize varieties. Experienced farmers can easily recognize some of the benefits of orange maize, such as early maturity, high yielding, and pest and drought tolerance. Furthermore, individuals who have grown or are at present growing proVA maize are likely to be familiar with the available planting materials, both local and the enhanced ones, as well as their source, price, and even the market for their produced maize.

Consumption of provitamin A maize

Some respondents agreed that eating orange maize is beneficial because it has been linked to fewer diabetes cases among their family members. This anecdotal knowledge is supported by the findings of Montonen *et al.* (2018), Midge *et al.* (2017), and Liu *et al.* (2000), who found that eating whole grain orange maize lowered the incidence of type 2 diabetes. Moreover, Khumalo *et al.* (2011) stated the need for the inclusion of vitamin A orange maize in meals as the reason for customers' preference over it. Therefore, farmers' recognition of the importance of proVAM intake are critical for reduced VAD among vulnerable groups.

Involvement of institutions in nutritional awareness and education on provitamin A maize

The results (Table 8) exhibit that the majority (83.3%) of the respondents did not receive any training on proVA maize and were unaware of the nutritional, health, and physiological importance of proVA maize in human body. On the other hand, the results demonstrate that only 16.7% of the respondents were trained by various organizations on the nutritional benefits of proVA maize. From the results, it can be told that large numbers of maize consumers are on darkness with regard to the knowledge on proVAM despite an involvement of several organizations on training the farmers. As shown in Table 8, institutions that have been involved in nutrition education on proVAM include local government officials (LGAs), particularly the agricultural field workers (AFOs) and nutritionists, Tanzania Agricultural Research Institutes (TARIs) such as TARI-Uyole, TARI-Serian, TARI-Dakawa, and TARI-Ilonga. Others are Meru Agro-Tours & Consultant seed Co Ltd (MATC), Charoen Pokphand (CP), and Sokoine University Graduate Entrepreneurs Cooperative (SUGECO).

The SUGECO, for example, has trained farmers on the cultivation of proVAM which has increased awareness on this nutritious maize among growers. They also worked with the seed companies and provided some proVAM seeds to farmers in the Kilosa district in Morogoro (CIMMYT, 2018). In addition to seeds, the farmers also received fertilizer as a starter kit for growing proVAM. All of these efforts done by SUGECO helped not only to create awareness but also to increase farmers' knowledge on the production and consumption of proVAM (Bechoff, 2013).

Khumalo *et al.* (2011) reported that the preference of some consumers for yellow maize was related to knowledge of proVA in yellow maize that was acquired in previous training courses. Shrestha & Karki (2015) insisted that more farmers and other stakeholders are impressed and encouraged to get involved in the production, processing, and distribution of proVAM after receiving training on the benefits of proVA. The study shows that the number of farmers who were trained is small compared to those who have not received training on nutrition, which means more strategies are still needed to ensure increased awareness of the importance of proVA maize among maize chain actors. Institutional support through training and information provision to farmers and other stakeholders in the provitamin-A-rich maize is therefore vital for increased production as well as consumption of this maize.

Farmer's perceptions on utilization of provitamin A-rich maize

The result on Fig. 5 represents farmers' perceptions on the use of yellow/orange maize, which are collectively referred to as yellow maize.

Yellow maize as animal feed

Respondents (38.5%) perceived yellow maize as animal feed (Fig. 5). Similar results were reported by Pillay *et al.* (2011) in a survey where respondents claimed to see yellow maize only in animal feed shops and not in human food markets.

Table 8. Institutions involved in training farmers on the production and consumption of provitamin A-rich maize.

Agro-ecological zone	Institutions/Organizations	Role in provitamin A production/consumption
Southern Highlands	TARI-Uyole (Mbeya)	-Research and germplasm conservation
	CIMMYT (Iringa)	-Train maize chain actors including seed companies and DAICOs (LGAs)
		-Provide proVA rich maize inbred lines to maize researchers
		-Provide small packs (100g) of proVA maize seed to plant to create awareness
Northern Highlands	TARI-Serian (Arusha)	-Research and germplasm conservation -Train farmers on the importance of proVAM
	Meru Agro-Tours & Consultant seed Co. Ltd (MATC)	-Test and release of proVA varieties (First company in the development of proVA maize seed in Tanzania)
		-Train farmers on production and consumption of proVA maize
		-Provitamin A (Meru VAH 517 & VAH 519) Seed dissemination
	Charoen-Pokphand	-Yellow maize seed dissemination (CP 201 & CP 808)
Eastern	TARI-Ilonga (Kilosa)	-Research and germplasm conservation,
	Meru Agro-Tours & Consultant seed Co. Ltd (MATC)	-Train farmers on production of proVA maize
	Building Nutritious Food Basket (BNFB)	-Research and distribution of proVA seed to farmers in Kilosa district
		-Create awareness among consumers on the importance of proVA maize
	SUGECO (Morogoro)	-Create nutritional awareness by training farmers on proVA rich maize
	Charoen-Pokphand (CP)	-Provide farmers training on yellow maize

SUGECO-Sokoine University Graduate Entrepreneurs Cooperative, TARI-Tanzania Agricultural Research Institute

The farmers' perception is also supported by the study by Tripathi *et al.* (2021) who reported that yellow maize are used as animal feeds. The study by Liu *et al.* (2012) state that eggs from poultry fed with yellow maize have bright egg yolk color which is associated with freshness and nutrient-dense, the qualities are preferential to customers yellow, orange, and red colours of feathers in some bird species are due to carotenoids, particularly xanthophyll, these colors have been useful in reproduction (Mcgraw & Ardia, 2003). In Tanzania, the livestock and poultry industry has grown over the past 10 decades and creates an opportunity for a number of people (BFAP, 2018; Naggujja *et al.*, 2020). The increased demand for quality meat in urban enlarges the number of consumers of meat from chicken, pigs, and cattle hence attracting more feed granulating industries for livestock. The development of the agricultural industry for animal feeds creates a market room for yellow maize hence attracting more farmers to venture into its production. The need for proVAM for livestock feeds, however, does not rule out the importance of this nutritious maize gratifying the VA requirements for human health. Odunitan-Wayas *et al.* (2016) suggested that feeding chickens with proVAM can be used as another strategy to improve vitamin A consumption by rural families especially those with a negative perception of yellow or orange maize.

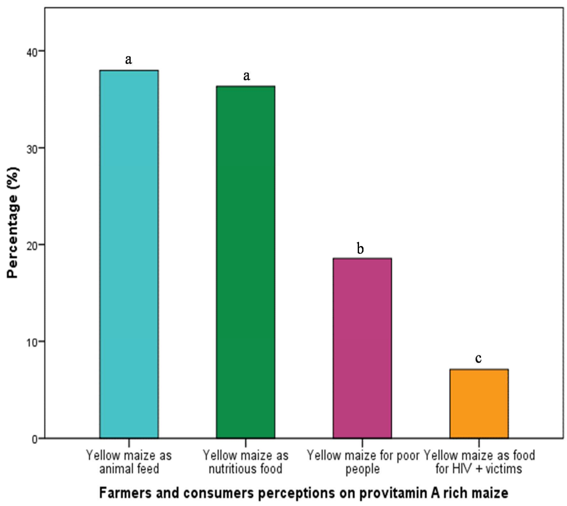

Fig. 5. Farmers' perception of proVAM as collected during 2020/2021 cropping season (bar plot with the with different letters are statistically significant different at 5% level of significance ($P<0.05$)).

Yellow maize as food for the poor

The other proportion of respondents (18%) perceived yellow maize as food for underprivileged individuals. The current results are consistent with those reported previously by Muzhingi *et al.* (2008). The link with yellow maize and poor resource families stems from the earlier as yellow maize was brought to Tanzania during times of famine, henceforth, that notion still exist among elders. As a result, for most Tanzanians, food security has been the consumption of white maize, this might have mainly been attributed by lack of the right information on other colored maize.

Meenakshi *et al.* (2010) argue that the right nutrition information can significantly amend consumers' perceptions and lead to a considerably higher possibility that nutritious orange maize would be consumed as food to all groups of human beings. Inadequate information over the yellow maize with regard to its contribution to the intake of VA, requires evidence-based participatory and rapid scalable strategies for awareness creation among maize actors and food stakeholders.

Yellow maize as nutritious human food

The results (Fig. 5) display that large proportion of farmers (37.5%) view proVA maize as a nutritious food. The present results harmonize with those of Ndwandwe (2018) and Schmaelzle *et al.* (2015), who suggested that to be effectively nourished, individuals must have access to adequate and high-quality food for better health. Additionally, the study by Muzhingi *et al.* (2008) insisted that nutritional information is the primary guide in household decision-making to purchase and use nutritionally biofortified maize. So, effective promotional campaigns and awareness creation are pivotal for increased acceptance of proVA maize by all the stakeholders i.e., seed dealers, farmers, consumers, nutritionists, and possessors.

Yellow maize as food for people living with human immunodeficiency virus (HIV) and acquired immune deficiency syndrome (AIDS)

The findings (Fig. 5) show that respondents perceived yellow maize to be useful to people who are living with the human immunodeficiency virus and acquired immune deficiency syndrome (PLWHA). The present findings are in line with Pustaka (2002), who suggests that PLWHA should take more micronutrients, such as Vitamin A, in addition to other dietary food groups. Furthermore, Rouf Shan *et al.* (2016), stated that maize has potential anti-HIV action due to the presence of Galanthus nivalis agglutinin (GNA-maize) lectin, which supports the farmers' understanding. According to Rouf Shan *et al.* (2016), lectins are unique proteins that bind to carbohydrate cell membranes and are thought to suppress the activities of microbes, including HIV. Yellow maize has also been blended with soya to make soya-enriched products that is rich in protein and vitamin A reported to be useful to HIV/AIDS patients as they repair worn out cell and improve body immune (Wilson & Lewis, 2015).

Yellow maize for sustenance aid in famine periods

The findings (Fig. 6) show that yellow maize is perceived as an aid food for the impoverished during the famine. The connection of yellow maize with food deficiency Tanzania is related to the historical background. According to Shao (1985), the country experienced a food scarcity in the 1980s, where the government imported yellow maize “yanga” as food aid during that drought calamity period. Since then, consumption of yellow maize has lacked consumer appeal particularly older Tanzanians who still relate it with relief food for the economically disadvantaged individuals. According to Mayer *et al.* (2008), yellow maize is a drought crop hence grown by poor resource societies in various SSA nations particularly in areas where rain is erratic. To the new generation of maize consumers, the colours association with famine assistance is expected to fade, and preference for proVAM may increase.

Thus, strategic promotion, awareness creation and the dissemination of nutritional knowledge is critical in changing the thinking of seniors on proVAM maize to accelerate its adoption. Some respondents showed awareness of the nutritional benefits of proVAM, implying that there is a bright future for adoption, which, if scaled up, might help to achieve the goal of provitamin A use in the fight against VAD.

Of importance to the above concerns, popcorn is an important snack consumed across sub-Saharan Africa without perceptions of kernel colors (white and yellow). This grants a chance in the maize sector to breed for popcorn varieties as consumption at present relies on imports due lack of adapted varieties suitable in tropical conditions (Ekpa *et al*., 2018).

Major challenges for production of provitamin A-rich maize in Tanzania

The main challenges highlighted to hinder production and consumption of proVAM in Tanzania were the low availability of proVAM seeds, lack of awareness about proVAM, high seed price, and poor extension services (Fig. 6).

Limited availability and accessibility of provitamin A maize seed

The results show that the availability of seeds (53%) was a major factor hindering the production of proVAM in their locality (Fig. 6). The study also observed that while there were very few proVAM seeds found in agro dealers' shops, there were no such seed in some maize growing areas during the cropping season. Hence, small number of farmers were involved in the production of proVAM in these areas due to unavailability seed. The problem might have been contributed by few (two proVAM) varieties that have been released in Tanzania i.e., Meru VAH 517 and Meru VAH 519 which might bring difficulties in the supplying required amount and inability to timely distribution of these varieties to all areas. This leads to high seed prices and inaccessibility among maize growers at large.

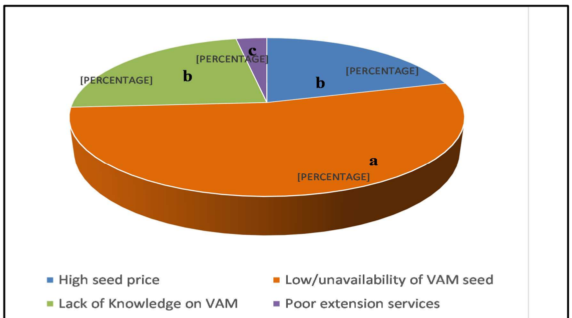

Fig. 6. Major challenges of production and adoption of proVAM in six districts of Tanzania (segment plots with different letters are statistically significantly different at a 5% level of significance (P<0.05).

Extension services

The results (Fig. 6) show that one of the drawbacks of producing proVAM in Tanzania is the lack of extension services. The current findings are consistent with that of Akinola & Nasa (2011) and Idrisa *et al.* (2012) who found that high seed prices, farmer awareness, and lack of extension services were among the major barriers to the adoption of improved maize varieties in Nigeria. Several researchers (Baloch & Thapa, 2019; Makingi & Urassa, 2017; Mwantimwa, 2020), have emphasized that extension services have been recognized as the most important factor in the rate of adoption of agricultural innovations. Nkonya *et al.* (1997) found that lowering hidden hunger was associated with disclosing farmers to extension services and utilization of nutritious maize varieties. Improving extension services could help farmers increase and strengthen awareness on improved maize varieties including proVAM.

Provitamin A maize seed price

The results (Fig. 6) reveal that proVAM seed costs more than normal maize seed. Meru and CP maize varieties were both sold at a higher price of nearly two times the price of white maize varieties on the market. A 2 kg bag of CP 201 and Meru VAH 517 maize, for example, costs 20,000 Tanzanian shillings (TZS), while a 2 kg package of UH 615 white maize costs only 11,500 TZS (Table 2).

During the study, the only farmer who grows CP 808 in Chimala (Mbarali district) stated that he bought his seed for TZS 11,000 per kg in the 2019/2020 cropping season. Due to the high price, the production and consumption of proVA maize are hampered. Lyimo *et al.* (2014) mentioned high price of improved maize seed as the most important factor as to why farmers do not prefer to use them. Therefore, seed supply stakeholders particularly those dealing with proVAM, should think of proper means that will help maize growers find seed easily available and affordable. For maize breeders, in particular, including proVA maize improvement in their programs imply and guarantee sustainable approach for seed availability to farmers.

Correlation of some characteristics with knowledge and perception of provitamin A-rich maize

Table 9) indicate strong and positive relationships between acres used in maize production and area of land owned (r=0.753), cost of seed and kind of maize seed (r=0.33), consumption of proVAM, and knowledge of proVAM (r=0.712), maize color preference, and knowledge of proVAM (r=0.663). Other notable connections included maize color preference and consumption (r=0.835), farmer perception of proVAM and knowledge of proVAM (r=0.495), farmer perception of proVAM and consumption of proVAM (r=0.640), and farmer

Correlations between examined parameters (

perception of proVAM and maize color preference (r=0.835), farmers' perceptions of proVAM and knowledge of proVAM (r=0.495), farmers' perceptions of proVAM and consumption of proVAM (r=0.640), farmers' perceptions of proVAM and maize color preference (r=0.669), and farmers' unwillingness to grow and land size owned (r=0.324). This shows that production, perception, and knowledge of provitamin A maize in Tanzania based on different agro-ecological zones depend on various factors which can work together. Therefore, any improvement needed will be the outcome of many factors under consideration.

Table 9. The Correlation between several variables and farmers' knowledge and perceptions of provitamin A-rich maize.

A		1	2	3	4	5	6	7	8	9
1	Education	1								
2	Land owned	0.06	1							
3	Type of seed	-0.049	-0.157**	1						
4	Knowledge	-0.007	-0.029	-0.093	1					
5	Consumption	0.06	0.039	-0.087	0.712**	1				
6	Preference	0.037	-0.043	-0.089	0.663**	0.835**	1			
7	Color - food	-0.037	0.068	0.057	-0.545**	-0.722**	-0.901**	1		
8	Perception	0.048	0.016	-0.031	0.495**	0.640**	0.669**	-0.544**	1	
9	Willing to grow	-0.006	0.081	-0.011	0.114*	0.205**	0.185**	-0.135**	0.156**	1
B					1		2		3	
1	Size of land				1					
2	Acres used				0.753**		1			
3	Cost of seed				0.102		0.182**		1	

Note: The correlation coefficients with asterisk and bold are statistically significant different at * <0.05, ** <0.01 and *** <0.001.

Conclusions and future trends

This study assessed farmers' knowledge, perceptions, and access to provitamin A-rich maize in Tanzania. Limited availability of correct information has made proVAM to be underutilized in alleviating the prevalence of VAD even among the vulnerable groups. In addition, the research related to farmers' knowledge, perception, and awareness of proVA rich maize is still scanty in the study area and the country at large. By considering the importance of maize as a staple crop for more than 65% of Tanzanians, a clear understanding of its nutritional attributes in alleviating VAD is worth to be studied. While few farmers are aware of the nutritional qualities of the provitamin A maize, there exists a large portion with an inadequate understanding of the nutritional importance of orange maize. Lack of awareness has been contributed by factors such as dwindling availability of yellow maize seed in agro-dealers shops in the study area, high seed price, as well as poor seed distribution. The farming experience of farmers in growing either local or improved yellow maize has a contributed to the knowledge and awareness of proVAM among farmers. Based on the current findings, it is concluded that farmers have a different understanding of provitamin A-rich maize.

Diverse perceptions that exist among farmers concerning the uses of yellow maize, justify the need for awareness campaigns on the potential of proVAM in fighting VAD. The understanding that yellow maize is useful as animal feed for livestock in respect to the growing livestock sector should be used as a bridge towards increased production of this maize. Ultimately, this conception may allow consumers to minimize VAD through eating animal products. As farmers vowed that yellow maize lacked market, incorporation of yellow maize in feed formulation might create the demand for more yellow maize in the future. Lack of nutritional education once well addressed might favour more farmers being involved in its production and consumption. The campaign and publication of the nutritional merits of yellow maize and its allied potential to reduce vitamin A deficiency can be achieved through appropriate educational means of awareness creation to farmers and consumers. The campaign strategies may include the use of leaflets, brochures, television, radio, and newspapers. Institutional support on information provision to farmers and stakeholders in the provitamin-A-rich maize is therefore vital for increased production as well as consumption of this maize. Good extension services delivery systems are crucial for capacitating farmers in their whole journey of crop production.

With few numbers of extension officers at lower administrative level i.e., the village, is likely farmers will not be attended due to ineffective extension services. Viewing extension services delivery systems to assure that agricultural experts are near to farmers and offer the appropriate agricultural extension services is inevitable. Facilitation of extension officers and monitoring on how they achieve their responsibility of reaching farmers seems important for awareness creation to farmers.

Considering high seed price of proVAM; deliberate strategies to ensure increased seeds production are required to be taken by breeder and seed companies for increased acreage that can upsurge consumption of provitamin A-rich maize among individuals. Maize breeders as key players in maize improvement, have to consider the inclusion of proVAM development in their breeding programs as a sustainable option. Furthermore, the seed companies should be stimulated to research, crop, and market proVAM varieties rich in b-carotene which will avail enough planting materials to maize growers. Therefore, further study should be conducted involving proVAM users in enlightens peer consumers and their involvement in participatory breeding techniques such as participatory seed and organoleptic evaluation.

Author Declarations

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Ethics approval/declaration

This study was given ethical approval by Tanzania Government through Ministry of Local Government Authority with permit reference number Ref.No.FA.255/265/01/05 for Mbeya and Iringa regions and Ref.No.DA.228/258/04/213 for Morogoro, Tanga and Kilimanjaro region.

Consent to participate

Verbal informed consent was obtained prior to the interview from all participants.

Consent for publication

Not applicable

Availability of data and material

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author contributions

S.D.M, A.A.M, P.B.V, and E.R.M; Conceptualization and methodology, S.D.M, A.A.M, and P.B.V; writing—original draft preparation, S.D.M, A.A.M, P.B.V, and E.R.M; writing—review and editing, A.A.M, P.B.V, and E.R.M Supervision, All authors have read and agreed to the published version of the manuscript.

Code availability (software application or custom code):
Not applicable

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References

Afzal SU, Ali N, Anjum MM, Usman H, Iqbal MO. 2017. Seed Yield Performance of Different Maize (*Zea mays* L.) Genotypes under Agro Climatic Conditions of Haripur **5(5).** https://doi.org/ 10.19080/ IJESNR.2017.05.555672.

Akinola MO, Nasa IDH. 2011. Analysis of adoption of improved maize varieties among farmers in Kwara State, Nigeria **1,** 8-12.

Akudugu MA, Guo E, Dadzie SK. 2012. Adoption of Modern Agricultural Production Technologies by Farm Households in Ghana: What Factors Influence their Decisions? Journal of Biology, Agriculture and Healthcare **2(3),** 1-13. https://www.researchgate.net/profile/Samuel_Dadzie/publication/235751741_Adoption_of_modern_agricultural_production_technologies_by_farm_households_in_Ghana_What_factors_influence_their_decisions/links/00463533b1249ebdf1000000.pdf

Aman M. 2021. Nutritional quality of pro-vitamin A, biofortified maize. March 10-18. https://doi.org /10.37446/jinagri/ra

Atta MM. 2016. Grain Protein, Oil and Starch Contents and Yields of Maize (*Zea mays* L.) as Affected by Deficit Irrigation, Genotype and Their Interaction Grain Protein, Oil and Starch Contents and Yields of Maize (*Zea mays* L.) as Affected by Deficit Irrigation. https://doi.org /10.9734/ IJPSS/ 2016 /23570.

Awobusuyi TD, Siwela M, Kolanisi U, Amonsou EO. 2015. Provitamin A retention and sensory acceptability of amahewu, a non-alcoholic cereal-based beverage made with provitamin A-biofortified maize. https://doi.org/10.1002/jsfa.7230

Bailey RL, West KP, Black RE. 2015. The epidemiology of global micronutrient deficiencies. Annals of Nutrition and Metabolism **66(suppl 2),** 22-33. https://doi.org/10.1159/000371618

Baloch MA, Thapa GB. 2019. Review of the agricultural extension modes and services with the focus on Balochistan, Pakistan. Journal of the Saudi Society of Agricultural Sciences **18(2),** 188-194. https://doi.org/10.1016/j.jssas.2017.05.001

Bartlett JE, Kotrlik JW, Higgins CC. 2001. Organizational Research : Determining Appropriate Sample Size in Survey Research **19(1),** 43-50.

Baudoin W, Nono-Womdim R, Lutaladio N, Hodder A, Castilla N, Leonardi C, Pascale S De, Qaryouti M. 2013. Good Agricultural Practices for greenhouse vegetable crops. In Good Agricultural Practices for greenhouse vegetable crops. https:// doi.org/10.1201/b13737-8

Bechoff A. 2013. A survey of traditional processing of sweet potato flour for amala, consumption pattern of sweet potato amala and awareness of orange-fleshed sweet potato (OFSP) in South West Nigeria. January.

BFAP. 2018. Structure and profitability of poultry value chains in Tanzania First draft. November 2018.

Biljon A Van, Labuschagne M. 2021. Multinutrient Biofortification of Maize (*Zea mays* L.) in Africa: Current Status, Opportunities and Limitations 1-24.

Braizer A, Armstrong J. 2014. Livelihoods and Food Security Programme Agriculture Productivity and Nutrition: The status of Biofortification in Zimbabwe. March.

Chen T, Gabrielyan G, Shimizu M, Qing P. 2021. The halo effect of biofortification claims on taste inference and purchase intention. British Food Journal. https://doi.org/10.1108/BFJ-07-2020-0614

CIMMYT. 2018. Building Nutritious Food Baskets Project.

Dalberg. 2019. Commercialization assessment: PVA Maize in Tanzania. December.

De Groote H, Kimenju SC. 2012. Consumer preferences for maize products in urban Kenya. Food and Nutrition Bulletin **33(2),** 99-110. https:// doi.org/10.1177/156482651203300203

De Groote H, Kimenju SC, Morawetz UB. 2011. Estimating consumer willingness to pay for food quality with experimental auctions: The case of yellow versus fortified maize meal in Kenya. Agricultural Economics **42(1),** 1-16. https://doi.org /10.1111 /j.1574-0862.2010.00466.x

Eakin H, Perales H, Appendini K, Sweeney S. 2014. Selling maize in Mexico: The persistence of peasant farming in an era of global markets. Development and Change **45(1),** 133-155. https:// doi.org /10.1111/dech.12074

Ekpa O, Palacios-Rojas N, Kruseman G, Fogliano V, Linnemann AR. 2018. Sub-Saharan African maize-based foods: Technological perspectives to increase the food and nutrition security impacts of maize breeding programmes. Global Food Security **17(March),** 48-56. https:// doi.org /10.1016/j.gfs.2018.03.007

FAOSTAT. 2021. Food and Agriculture Organization of the United Nations. (2021). FAOSTAT statistical database *[http://faostat3.fao.org/browse/Q/*/E]*. [Rome] : FAO, c1997-. https://search. library. wisc.edu /catalog /999890171702121

Fragoso YD, Campos NS, Tenrreiro BF, Guillen FJ. 2012. A systematic review of the literature on vitamin A and memory. Dementia & Neuropsychologia **6(4),** 219-222. https://doi.org/10.1590/s198057642012dn06040005

Fraser PD, Bramley PM. 2004. The biosynthesis and nutritional uses of carotenoids **43,** 228-265. https://doi.org/10.1016/j.plipres.2003.10.002

Gethi J, Maru J. 2017. Facts on Provitamin A (PVA) Maize : Situational analysis report for biofortification and biofortified crops in Tanzania. International Potato Center **2(ISBN 978-92-9060-485-3.),** 80.

Harika R, Faber M, Samuel F, Mulugeta A, Kimiywe J, Eilander A. 2017. Are Low Intakes and Deficiencies in Iron, Vitamin A, Zinc, and Iodine of Public Health Concern in Ethiopian, Kenyan, Nigerian, and South African Children and Adolescents ? **38(3),** 405-427. https:// doi.org/ 10.1177 /0379572117715818

Harjes CE, Buckler ES, Rocheford TR, Kandianis CB, Bai L, Brutnell TP, Sowinski SG, Williams M, Stapleton AE, Vallabhaneni R, Wurtzel ET, Yan J. 2008. Natural genetic variation in lycopene epsilon cyclase tapped for maize biofortification. Science **319(5861),** 330-333. https: // doi.org/10.1126/science.1150255

Idrisa Y, Shehu H, Ngamdu M. 2012. Effects of Adoption of Improved Maize Seed on Household Food Security in Gwoza Local Government Area of Borno State, Nigeria 12(5).

Israel GD. 2003. Determining Sample Size.

Jenkins M, Shanks CB, Brouwer R, Houghtaling B. 2018. Factors affecting farmers ' willingness and ability to adopt and retain vitamin A-rich varieties of orange-fleshed sweet potato in Mozambique 1501-1519.

Kathage J, Qaim M, Kassie M, Shiferaw BA. 2013. Big Constraints or Small Returns? Explaining Nonadoption of Hybrid Maize in Tanzania, Global Food Discussion Papers **No. 19,** Georg-August-Universität Göttingen, Research Training Group (RTG) 1666. Global Food, Göttingen.

Khan N. 2019. Factors Affecting Maize Productivity of Credit Owner Farmers of Zarai Taraqiathi Bank Limited in Rural Area of District **10(5),** 62-72. https://doi.org/10.7176/JESD

Khumalo TP, Schönfeldt HC, Vermeulen H. 2011. Consumer acceptability and perceptions of maize meal in Giyani, South Africa. October **2014,** 37-41. https://doi.org/ 10.1080/ 0376835X. 2011. 74

Liu YQ, Davis CR, Schmaelzle ST, Rocheford TME, Cook A, Tanumihardjo SA. 2012. β-Cryptoxanthin biofortified maize (*Zea mays*) increases β-cryptoxanthin.

Makingi G, Urassa JK. 2017. Socio-Economic Factors Influencing Use of Improved Technologies by Smallholder Paddy Farmers in Kilombero District, Tanzania.

Maqbool MA, Aslam M, Beshir A, Khan MS. 2018. Breeding for provitamin A biofortification of maize (*Zea mays* L.). Plant Breeding **137(4),** 451-469. https://doi.org/10.1111/pbr.12618

Mayer JE, Pfeiffer WH, Beyer P. 2008. Biofortified crops to alleviate micronutrient malnutrition. June 2018. https://doi.org /10.1016 /j.pbi.2008.01.007

Mcgraw KJ, Ardia DR. 2003. Carotenoids, Immunocompetence, and the Information Content of Sexual Colors: An Experimental Test **162(6).**

Meenakshi JV, Banerji A, Manyong V, Tomlins K, Hamukwala P, Zulu R, Mungoma C. 2010. HarvestPlus Working Paper Consumer Acceptance of Provitamin A Orange Maize in Rural Zambia. English, 4.

Mng'ong'o M, Munishi LK, Blake W, Comber S, Hutchinson TH, Ndakidemi PA. 2021. Soil fertility and land sustainability in Usangu Basin-Tanzania. Heliyon **7(8),** e07745. https://doi.org /10.1016 /j.heliyon.2021.e07745

Mulongo G, Munyua H, Maru J, Mnzava M, Kasuga R, Olapeju P. 2017. Situational analysis report for biofortification and biofortified crops in Tanzania. Nairobi (Kenya). International Potato Center (CIP). ISBN 978-92-9060-485-3. 80 p.

Muzhingi T, Langyintuo AS, Malaba LC, Banziger M. 2008. Consumer acceptability of yellow maize products in Zimbabwe. Food Policy **33(4),** 352-361. https://doi.org/10.1016/j.foodpol.

Mwantimwa K. 2020. Livelihood information and knowledge needs, access, and exchange in rural communities in the Bunda District, Tanzania. Rural Society **29(1),** 30-43. https://doi.org/10.1080/ 10371656. 2020.1744271

Naggujja J, Njiru N, Msoffe P, Naazie A, Kelly T, Enahoro D, Ouma E. 2020. Tanzania and Ghana Poultry Sector Policy Review September 2020. September.

Ndau EL, Walters D, Wu D, Saleh N, Mosha TCEHSL. 2016. Factors Influencing Vitamin A Status of Lactating Mothers in Manyara and Shinyanga Regions of Tanzania **15(1),** 21-32.

Ndwandwe NK. 2018. Sensory quality of provitamin A biofortified maize-based foods and the effect of a provitamin A biofortified maize awareness campaign on their acceptance in KwaZulu-Natal, South Africa.

Negatu W, Parikh A. 1999. The impact of perception and other factors on the adoption of agricultural technology in the Moret and Jiru Woreda (district) of Ethiopia. Agricultural Economics **21(2),** 205-216. https://doi.org/10.1016/S0169-5150(99)

Ngailo JA, Mwakasendo JA, Kisandu DB, Tippe DE. 2017. Rice Farming in the Southern Highlands of Tanzania: Management Practices, Socio-Economic Roles and Production Constraints. European Journal of Research in Social Sciences **4(4),** 13.

Nkhata SG, Chilungo S, Memba A, Mponela P. 2020. Biofortification of maize and sweet potatoes with provitamin A carotenoids and implication on eradicating vitamin A deficiency in developing countries. Journal of Agriculture and Food Research **2(July),** 100068. https://doi.org/10.1016 /j.jafr.

Nkonya E, Schroeder T, Norman D. 1997. Factors Affecting Adoption of Improved maize in Tanzania.

Nuss ET, Arscott SA, Bresnahan K, Pixley KV, Rocheford T, Hotz C, Siamusantu W, Chileshe J, Tanumihardjo SA. 2012. Comparative intake of white- versus orange-colored maize by Zambian children. Food & Nutrition Bulletin **33(1),** 63-71.

Nyeko P, Stewart J, Franzel S, Barklund P. 2004. Farmers' experiences in the management of pests and diseases of calliandra calothyrsus in Uganda. Uganda Journal of Agricultural Sciences **9(1),** 520-529.

Oikesh SO, Menker A, Mziya-Dixon B, Welch R, Glahn PR. 2003. Assessment of Fe and Zn in Maize. Journal of Agricultural Food Chemistry **51(12),** 3688-3694.

Okello JJ, Sindi K, Shikuku K, Mcewan M, Low J. 2017. A Study of Household Food security and Adoption of Biofortified Crop Varieties in Tanzania : The Case ofOrange-Fleshed Sweetpotato. InTech (Open Science /Open Mind.

Olson JA. 1987. Recommended dietary intakes (RDI) of vitamin A in humans.

Oniang RK, Mutuku JM, Malaba SJ. 2003. Contemporary African food habits and their nutritional and health implications **12(June),** 231-236.

Oteh OU, Hefferon K, Agwu NM. 2020. Moving Biofortified Cassava Products Closer to Market in Nigeria **4,** 1-11. https://doi.org /10.3389 /fsufs. 2020.

Palacios-Rojas N, McCulley L, Kaeppler M, Titcomb TJ, Gunaratna NS, Lopez-Ridaura S, Tanumihardjo SA. 2020. Mining maize diversity and improving its nutritional aspects within agro-food systems. Comprehensive Reviews in Food Science and Food Safety **19(4),** 1809-1834. https:// doi.org/10.1111/1541-4337.12552

Pillay K, Derera J, Siwela M, Veldman F. 2011. Consumer acceptance of yellow, provitamin A-biofortified maize in KwaZulu-Natal. South African Journal of Clinical Nutrition **24(4),** 186-191. https:// doi.org/10.1080/16070658.2011.11734386

Pustaka T. 2002. Good Nutrition for Quality of Life of PLWHA (People Living with HIV/AIDS) 29-34.

Ranum P, Pe JP. 2014. Global maize production, utilization, and consumption. March. https://doi.org /10.1111/nyas.12396

Rouf Shah T, Prasad K, Kumar P. 2016. Maize: A potential source of human nutrition and health: A review. Cogent Food & Agriculture **2(1).** https:// doi.org/10.1080/23311932.2016.1166995

Sánchez-Toledano BI, Kallas Z, Rojas OP, Gil JM. 2018. Determinant factors of the adoption of improved maize seeds in Southern Mexico: A survival analysis approach. Sustainability (Switzerland) **10(10).** https://doi.org/10.3390/su10103543

Santpoort R. 2020. The drivers of maize area expansion in sub-Saharan Africa. How policies to boost maize production overlook the interests of smallholder farmers. Land **9(3).** https://doi.org /10.3390 /land9030068

Schmaelzle S, Kaliwile C, Arscott SA, Gannon B, Tanumihardjo SA. 2015. Nutrient and nontraditional food intakes by Zambian children in a controlled feeding trial. Food Nutr Bull **35(1),** 60-67.

Schroeder C, Onyango K'Oloo T, NB R, NA J, DC G, HK P. 2013. Potentials of Hybrid Maize Varieties for Small-Holder Farmers in Kenya: A Review Based on SWOT Analysis. African Journal of Food, Agriculture, Nutrition and Development **13(2),** 7357-7371.

Shao J. 1985. Politics and the Food Production Crisis in Tanzania **14(1985),** 10-24.

Shrestha J, Karki TB. 2015. Provitamin A Maize Development: A Strategy for Fighting against Malnutrition in Nepal. Our Nature **12(1).**

Sinbad OO, Folorunsho AA, Olabisi OL. 2019. Vitamins as Antioxidants **2(3),** 214-235. https:// doi.org /10.26502/jfsnr.2642-11000021

Stephen L, Zubeda M, Hugo DG. 2014. The use of improved maize varieties in Tanzania. African

Journal of Agricultural Research **9(7),** 643-657. https://doi.org/10.5897/ajar11.065

Suleiman R. 2018. Local and regional variations in conditions for agriculture and food security in Tanzania: A review.

Titcomb TJ, Tanumihardjo SA, Mcculley L, Gunaratna NS, Kaeppler M, Lopez-ridaura S. 2020. Mining maize diversity and improving its nutritional aspects within agro-food systems. February, 1-26. https://doi.org/10.1111/1541-4337.

Tripathi MP, Koirala KB, Gautam D. 2021. Field Performance of Three-way Cross Yellow and White Maize Hybrids in Nepal. March. https:// doi.org /10.9734 /AJAAR/2021/v15i130144

Udimal TB, Jincai Z, Mensah OS, Caesar AE. 2017. Factors Influencing the Agricultural Technology Adoption : The Case of Improved Rice Varieties (Nerica) in the Northern Region, Ghana **8(8),** 137-148.

United Republic of Tanzania. 2020. National Biofortification Guidelines, Ministry of Agriculture. May, 2020.

Urass KJ. 2015. Factors influencing maize crop production at household levels: A case of Rukwa Region in the southern highlands of Tanzania. African Journal of Agricultural Research **10(10),** 1097-1106. https://doi.org/10.5897/ajar2014.9262

Wilson RT, Lewis J. 2015. The Maize Value Chain in Tanzania A report from the Southern Highlands Food Systems Programme.

Wurtzel ET, Cuttriss A, Vallabhaneni R. 2012. Maize Provitamin A Carotenoids, Current Resources, and Future Metabolic Engineering Challenges. Frontiers in Plant Science **3(February),** 1-12. https://doi.org/10.3389/fpls.2012.00029

Yarnell A. 2008. Feeding Africa. Chemical and Engineering News **86(4),** 74. https://doi.org /10.1021/ cen-v086n004.p074

Zuma MK. 2019. Farmer Perceptions on South African Popular Maize Varieties: A Proxy for the Integration of Provitamin A Biofortified Maize into Smallholder Farming System.