EISSN: 2707-0425

East African Journal of Science, Technology and Innovation, Vol. 4 (Special Issue): August 2023

Unlocking the potential for yellow maize production and utilization in Homa-bay County, Kenya

[1*]AGUK J A., [1]ONWONG'A R N., [2]CHEMINING'WA G., [3]JUMBO M B., [4]ABONG' G O

[1]Department of Land Resource Management and Technology, University of Nairobi, P.O. Box 29053-00625, Kangemi, Kenya
[2]Department of Plant Science and Crop Protection, University of Nairobi, P.O. Box 29053-00625, Kangemi Kenya
[3]International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Matopos Research Station, P.O. Box 776, Bulawayo, Zimbabwe
[4]Department of Food Science, Nutrition and Technology, University of Nairobi, P.O. Box 29053-00625, Kangemi Kenya
***Corresponding Author**: joycaguk@gmail.com

Abstract

Yellow maize is popular in Western Kenya especially in Homa-Bay County. However, it's faced with myriad of challenges that has greatly limited its production and utilization. This study investigated yellow maize production, post-harvest handling and utilization practices and constraints while exploring opportunities. The study was conducted from September-November 2020 in three wards of Ndhiwa Sub-County, Homa-Bay County by conducting a cross-sectional survey using a structured questionnaire administered to 385 farmers. Results showed that yellow maize production was an important food security crop and source of livelihood for farmers. Yellow maize was continuously cultivated as a sole crop or intercropped with legumes in less than 1ha land sizes using locally sourced seed with low levels of farm inputs resulting in low yields of less than 1 t/ha. Yellow maize was preferred due to its early maturity (3 months), taste, tolerance to biotic and abiotic stresses. The main constraints included total lack of good quality seed, low soil fertility (71%), striga weed infestation (60%), low marketability (46%), pest/diseases prone (34%) and adverse weather (33%). About 68% sun dried their maize, with the dried grains stored in polypropylene bags (87%) kept mainly on raised platforms in their houses (90%) for approximately 3 months/year. Most of the respondents (95%) preferred to consume yellow maize compared to white maize mainly in form of *ugali* (stiff porridge) (97%) consumed twice daily (77%). The yellow maize potential is under-exploited and enhancing its productivity through research, improved seed system, soil amendments and awareness creation could lead to production increase and be among the pathways that can be used to develop the region and contribute to food and nutrition security in the country.

Keywords: *Homa-Bay County; survey; vitamin A; yellow maize*

Cite as: Aguk *et al. (2023)* Unlocking the potential for yellow maize production and utilization in Homa-bay County, Kenya. *East African Journal of Science, Technology and Innovation Vol. 4 (Special Issue).*

Received: 26/06/2023
Accepted: 06/07/2023
Published:09/08/23

Introduction

Maize is one of the top most produced cereal crop worldwide that is used mainly as livestock feed with a small percentage used directly as human food (Mulungu *et al.,* 2018). In Latin America, Africa and Asia, maize is the main staple food acting as a key source of energy. Major food crops in Kenya are maize, wheat, rice and potato. Maize has, however, established itself as the dominant crop cultivated on over two million hectares country wide in various agro-ecological zones with a production of about four million tonnes (FAO, 2020). Over 60% of the farming community consists of small-scale farmers with average land sizes of less than I ha from where they produce most of the food and also derive their livelihood and nutritional needs (Rapsomanikis, 2015). Maize therefore forms a major portion of daily dietary intake with an average consumption rate of 64 kg/person/year which is among the highest in the world (KNBSa, 2019a; Ranum *et al.,* 2014). However, on-farm maize productivity has declined considerably over the last decades and this can be attributed to poor soil fertility and degradation, diseases, pests and weeds (Striga weed), adverse effects of climate change and human population pressure (Aguk *et al.,* 2021). This has led to major emphasis being placed on increased agricultural production as the key to ensuring food security in the country.

Another key concern is the quality of maize in terms of nutrient composition, an important aspect that has altered the scenario that focused on yields to curb food insecurity but accentuated further to tackle the problem of nutrition insecurity and malnutrition (Poole *et al.,* 2021). This is mainly due to the fact that white maize is the most consumed in many Kenyan households both in rural and urban areas providing most of the calories needed although it is devoid of essential micronutrients including vitamin A that is critical for good health (Manjeru *et al.,* 2017). The white maize is also associated with social status accompanied with the notion that 'the whiter the better' with people willing to pay premium price to eat white maize rather than yellow maize (De Groote & Chege, 2008). Over reliance on white maize as the primary staple food in most households has led to malnutrition which mostly affects children under the age of five and women in their reproductive such as Vitamin A deficiency (VAD) (Ekpa *et al.,* 2018). This offers a compelling reason for urgent complementary sustainable interventions to address the issue. Hence use of well-established staple crops such as maize that are frequently consumed in large quantities by the bulk proportion of the rural resource poor and as infant food may provide a promising alternative (Manjeru *et al.,* 2017; Talsma *et al.,* 2017). Yellow maize is promising as it can serve as a source of vitamin A since it has natural available carotenoids, a precursor for vitamin A synthesis, that is responsible for the yellow color (Kuhnen *et al.,* 2011).

There are, however, challenges associated with its production that must be tackled to unlock its potential. It is, for instance, widely considered as an inferior crop synonymous with food aid, disliked due to color and flavor change it imparts to food that people find unacceptable hence highly reserved as livestock feed (Aguk *et al.,* 2021; Muzhingi *et al.,* 2008; McCann, 2005). The extent of neglect is confirmed by the lack of production statistics on yellow maize in Kenya which have restricted its production and consumption in the rural areas mainly in western part of Kenya. Consequently, any potential benefits it could confer are negated exposing farmers involved in its production to a myriad of challenges responsible for the low productivity. This study, therefore, seeks to investigate yellow maize production, handling and utilization that is local in this region, where impact and adoption is expected to be much easier. The information would support possible ways of creating and undertaking awareness campaigns to popularize and promote yellow maize among the wider community and other relevant stakeholders and help to influence behavioral change. It further seeks to identify challenges faced by yellow maize farmers in order to help inform and design intervention strategies that can unlock its potential.

Study Approach

Description of the study site

The survey was conducted in Homa-Bay County situated in South Western Kenya along Lake Victoria at an altitude of approximately 1,220 meters above sea level covering 3,154.7 km^2 (Figure 1). It is located at 0°31'38.3'' S and 34°27.428' E latitude with a population of 1,131,950 people and 262,036 households out of which 43.7% of the population live in abject poverty (KNBS, 2019b). The County experiences a bimodal rainfall pattern with long rains falling between March and May averaging 300mm-800mm and the short rains in September and November averaging 100mm-400mm with annual mean temperatures of 26^{0}C-34^{0}C (Ogenga, 2021). The region covers upper and lower midland Agro-ecological zone and mainly consisting of Humic Andosols, Orthic and Plinthic Acrisols soil types (Luedeling, 2011; MoALF, 2016). The main economic activities include fishing due to proximity to Lake Victoria and agriculture especially in Kasipul, Kabondo, Rangwe and Ndhiwa producing mainly cereals such as yellow maize, sorghum and millet.

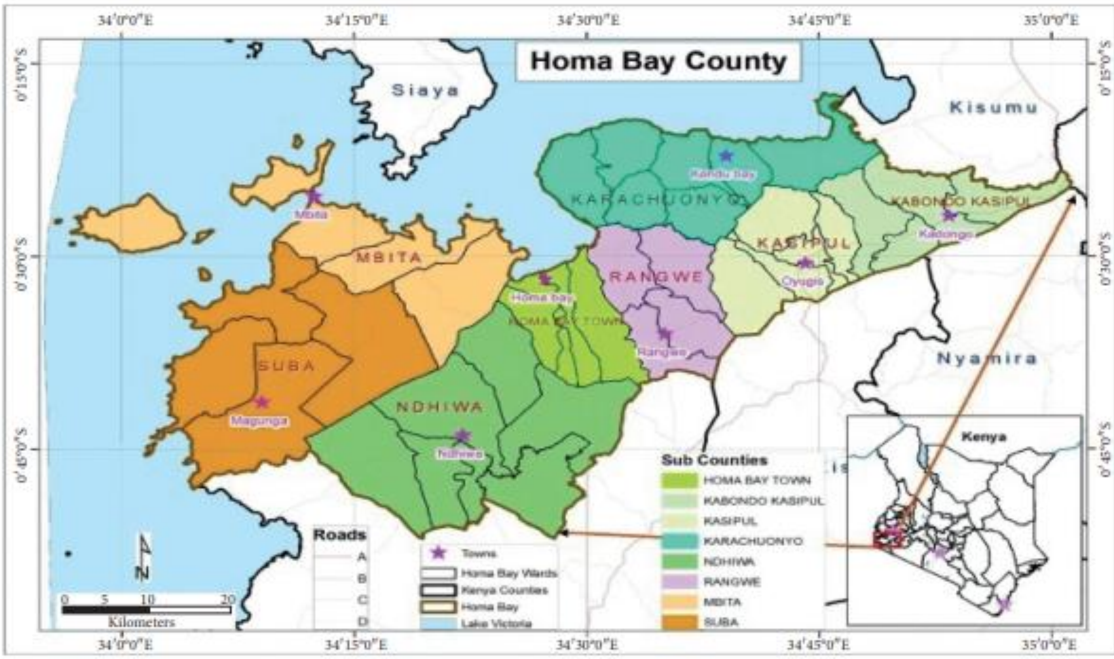

Figure 1. A map of Homa-bay County. Source:(CIDP, 2018)

Sample size determination

The minimum population sample size of 384 respondents was determined by Fisher et al. (1998), as per equation (1)

$$n = \frac{z^2pq}{d^2} \quad (1)$$

Where z= 95% confidence (1.96)

p= Percentage of farmers growing yellow maize. Since it is unknown 0.5 was adopted to provide as precise as possible maximum required sample size (Kothari & Garg, 2014)

q=1-p

d= Margin of error (0.05%)

therefore $\frac{1.96^2 \times 0.5 \times 0.5}{0.05^2} = 384$

Sampling criteria

Ndhiwa sub-county in Homa-Bay was purposively sampled as it is a major yellow maize growing region (Adavachi, 2017). There were four wards surveyed due to the comparatively large number of farmers engaging in yellow maize production and ease of accessibility. The number of respondents was distributed proportionately to population as 36% (140) in Kanyamwa Kologi, 17% (65) in West Kanyamwa, 27% (103) in Riana West and 20% (77) in Central Kanyamwa. Specific villages in each ward were sampled randomly for individual interviews.

Data collection

Data was collected using a structured questionnaires using Open Data Kit (ODK) data collection software administered with the assistance of college students recruited and trained as enumerators for this purpose. Due to COVID 19 pandemic that restricted movements across counties, the enumerators came from the targeted County and to ensure efficiency in data collection they were also highly knowledgeable of the study area and could speak the local language. The enumerators were trained on ethics in data collection, administration of the questionnaire and operation of the ODK application. Each question was examined with the enumerators to determine the appropriateness and clarity of questions and where necessary questions with queries were reviewed by adding, removing or revising the question. The questionnaire was then pre-tested on a small sample of ten farmers in a neighboring ward involved in yellow maize production of which the data collected was not included in this study. The first page of the questionnaire contained the consent form that explained the research project overview and participant's confidentiality, making sure that their personal information would remain confidential and they hold the right to withdraw from the interview whenever they wish to. The questionnaire captured data on famer sociodemographic characteristics, current production and post-harvest practices and utilization of yellow maize.

Statistical analysis

Statistical Package for Social Sciences (SPSS) version 20 was used for data analysis. Chi-square or Fisher Exact tests were used to analyze continuous data and categorical data, respectively. The descriptive statistical analysis was undertaken for demographic variables. Pearson correlation analysis was used to investigate the relationship between production constraints and sociodemographic features and the associations were expressed as Odds Ratio 9 (OR) at 95% Confidence Interval (CI). A P-value was considered statistically significant at a 95% confidence level (P ≤0.05, 2-tailed test).

Results

Socio-demographic characteristics of the study population

Out of the 385 respondents, 57% were women with all the wards registering more females than males (Table 1). Overall, there was a significant difference ($p<0.05$) in the age of the respondents with nearly half of the respondents (48%) being middle aged (35-60 years) while 35% were youths (18-35 years) with the majority being married (72%) and about half (51%) having attained secondary and tertiary level of education. Household size averaged 5 members and a higher proportion (66%) depended on farming as their main source of income.

Table 1. Social demographic characteristics of respondents from Ndhiwa, Homa-Bay County

Demographic and socioeconomic characteristics	Ward							
	KK	WK	RW	CK	Total	x	df	p value
Number of respondents	140	65	103	77	385			
Gender (%)						6.985	3	.072
Male	17.7	4.9	11.9	8.3	42.8			
Female	18.7	11.9	14.8	11.7	57.1			
Age of respondents(%)						13.64	6	.034
Youth (18-35 years)	11.2	8.6	9.4	6.2	35.4			
Middle Aged (35-60 years)	17.4	5.7	14.5	10.4	48			
61 years and above	7.8	2.6	2.9	3.4	16.7			
Marital status (%)						11.32	6	.079
Married	27.5	11.2	18.2	15.3	72.2			
Single	2.1	2.3	3.1	0.3	7.8			
Widowed/Widower	6.8	3.4	5.5	4.4	20.1			
Education level (%)						60.26	15	.000
No formal education	4.7	2.3	5.5	1.3	13.8			
Some primary school	4.4	4.7	7.0	3.6	19.7			
Completed primary school	3.6	3.9	5.2	1.6	14.3			
Some secondary school	9.4	1.0	2.6	3.1	16.1			
Completed secondary school	9.4	3.1	3.9	8.8	25.2			
Tertiary education	9.9	1.8	2.6	1.6	15.9			
Main source of income (%)						17.75	6	.007
Farming	25.0	11.4	15.0	14.0	65.5			
Employed/Salaried	4.7	0.3	2.9	1.6	9.4			
Business/retail activities	6.2	5.2	9.4	4.4	25.2			
Household size (%)						15.57	6	.016

1-5	23.6	11.4	21	10.7	66.7
5-10	12.5	5.2	5.7	9.4	32.8
>10	0.3	0.3	0	0	0.6

KK= Kanyamwa Kologi, WK=West Kanyamwa, RW= Riana West, CK=Central Kanyamwa

Yellow maize was regarded as the most important food security crop by all the respondents, followed by beans (62%) and groundnuts (31%) (Figure 2). Despite this, yellow maize yields were very low with majority (92%) attaining yields less than 1 t/ha.

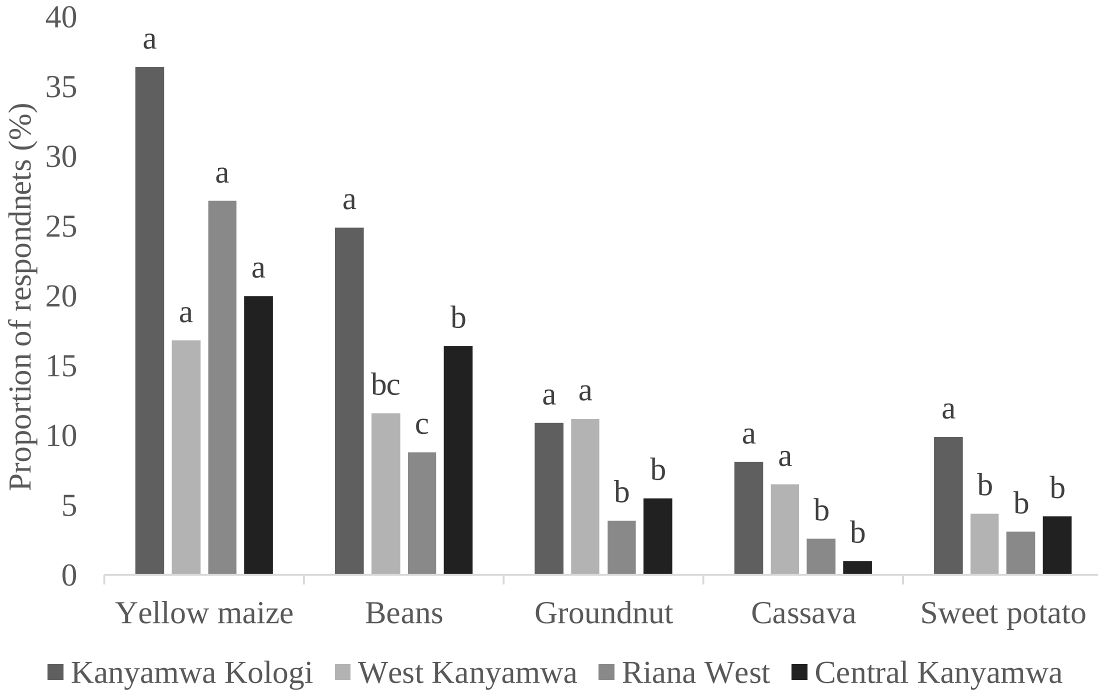

Figure 2. Priority food security crops in Ndhiwa, Homa-Bay. Different letters for an attribute indicate significant difference at $p < 0.05$

Land ownership and use

About 78% had access to one or two pieces of land with an average land size of 0.4 ha. Generally, 80% of the land parcels were freehold having title deeds. Half the farms were within the homestead for ease of access while 33% were barely a kilometer away. The land parcels were majorly used for crop production constituting 75% while the rest were used for mixed farming (crop and livestock production).

Yellow maize production systems and attributes

In both the long and short rain seasons, sole cropping was practiced in about 75% of the lands with major crops grown being yellow maize (70%), beans (30%) and groundnuts (9%). Ninety-five percent of the farmers produced the said crops for home consumption.

Farmers predominantly grew local maize landraces which were either yellow or white. However, 18% of farmers except from Central Kanyamwa cultivated local maize with improved maize varieties. Since the farmers targeted in this survey were yellow maize farmers, they all mentioned the local yellow maize cultivar '*Nyamula*' which in Luo dialect means yellow. Other names of local maize cultivars grown included *Kongere*, *Jowi Jamuomo*, *Nyaugenya*, and *Nyauyoma*. There were several names of improved maize cultivars mentioned; DK 80-31, DK80-33, Duma 43, Punda Milia 51 and Pioneer, all of which were white maize.

Farmers were asked to share reasons for growing yellow maize. There were 13 desirable attributes of yellow maize given by 320 of the respondents as shown in Table 2. The most preferred yellow maize attributes mentioned by almost all respondents was early maturity and taste (sweet), with half preferring it due to its drought tolerance and nutritive value. The respondents did not mention any undesirable attributes of yellow maize. White maize varieties were preferred by only 65% of the respondents due to good market price (42%), availability of certified seeds (40%), high yields (19%), and preference among family members (3%). Undesirable attributes of white improved maize were that it was prone to pests and diseases as reported by 57%, highly affected by adverse weather conditions (18%), requires fertilizer application and purchase of certified seeds (16% and 10%, respectively).

*Table 2***.** *Desirable attributes of yellow maize grown in Ndiwa, Homabay*

	Desirable attribute	**%**
i.	Early maturity	25
ii.	Tasty/sweet	24
iii.	Drought tolerant	14
iv.	High nutritive value	13
v.	Availability of local seeds	9
vi.	Little fertilizer required	8
vii.	Quickly satisfies hunger	8
viii.	Striga weed tolerant	6
ix.	High yielding	4
x.	Pest tolerant	2
xi.	Accustomed to consuming it	2
xii.	Marketable	1
xiii.	Color	0.2

An estimated 74% of the farmers had grown yellow maize for a period of between 1-10 years. There was significant difference ($P<0.05$) in the type of cropping system used with 68% of the respondents preferring intercropping of yellow maize mainly using legumes such as beans (92%) and groundnuts (28%) to sole cropping. Other crops (2%) used for intercropping were cassava, sugarcane, cowpea, green grams, sorghum, sweet potato and soybean. Key reasons the farmers practiced intercropping yellow maize with legumes was for improved yields and soil fertility enhancement each at 50% of the respondents. Other reasons included insurance against crop failure (43%), reducing weed infestation (34%), crop diversification (24%) and reducing pests and diseases (17%).

There were significant differences ($p < 0.05$) between the seasons the farmers grew their yellow maize with majority of the farmers (81%) practicing continuous maize cultivation (growing in both the short and long rainy season) while 11% preferred to grow maize only during the short rainy season (Figure 3). For majority (84%) of the respondents, the period between planting and harvesting was basically 3 months.

Constraints in yellow maize production

Yellow maize seeds were mainly sourced from informal channels with 81% of the farmers using farm saved seeds from previous harvests, 13% bought their seeds from the local market while 5% used both of these channels. There was no farmer who planted certified yellow maize seeds since these were not available. Farmers used varied spacing when planting yellow maize with only 12% being specific to spacing of 60cm by 30cm.

About 58% of the farmers indicated that they were experiencing problems with yellow maize production with the majority being from Kanyamwa Kologi and Central Kanyamwa wards (Figure 4).

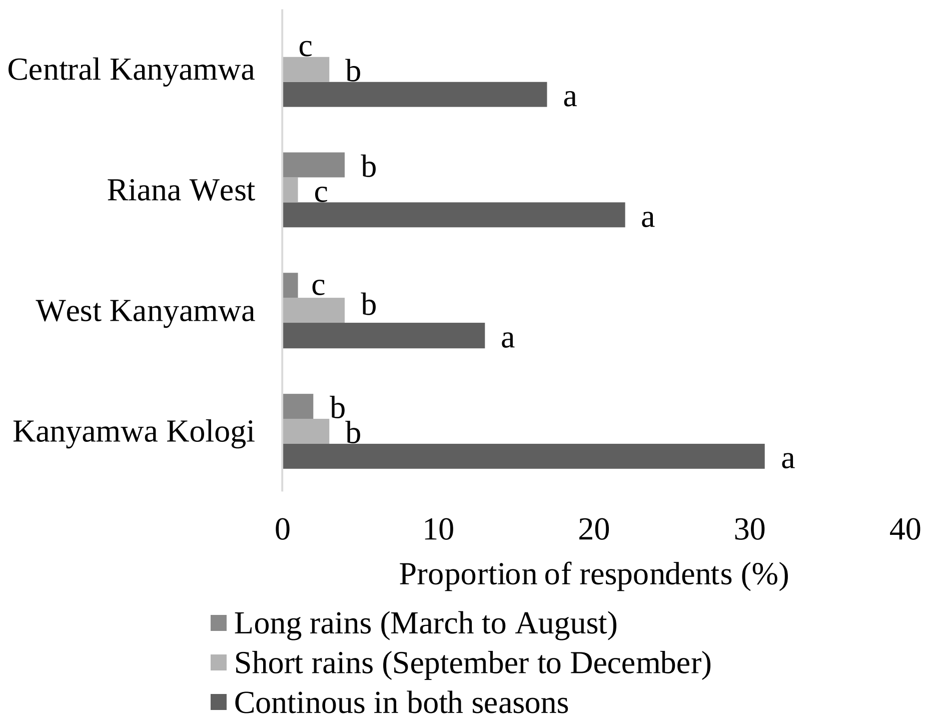

Figure 3. Seasons for growing maize in the study region. Different letters indicate significant difference at p < 0.05

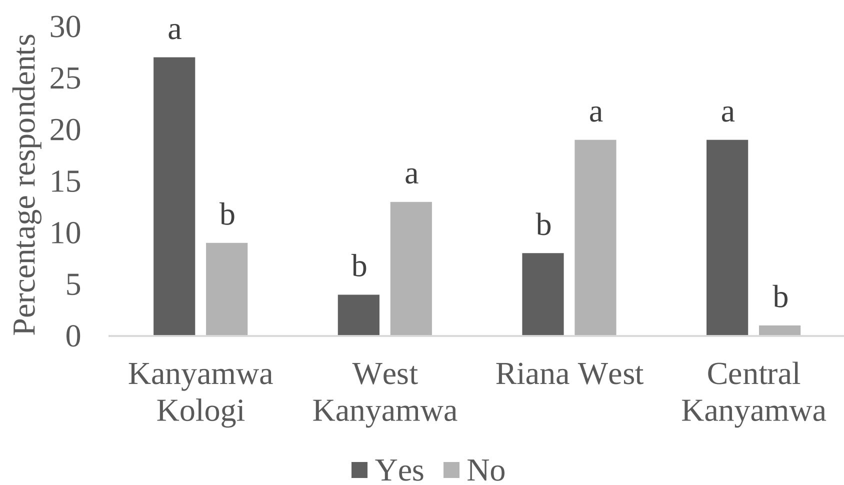

Figure 4. Farmers' response on whether they experienced problems in yellow maize production. Different letters indicate significant difference at p < 0.05

The relationship of the respondents' demographic characteristics compared with those who either responded yes or no to facing problems with yellow maize production showed gender and main source of income having significant positive predictor influence (Table 3). It indicates that men (B=0.5, OR=1.7) and those engaged in farming (B=0.9, OR=2.6) were more likely to have challenges in yellow maize production compared to the women and those who were self-employed. On the other hand, education had significant negative influence with those having no education (B=-1.7 OR=0.2) and with some primary education (B=-1.0, 0R=0.4) less likely to face challenges relative to those having tertiary education.

Table 3. Social demographic characteristics influencing whether farmers are facing constraints with yellow maize production in Ndhiwa Sub-County in Homabay County

Demographic characteristics	**Categories**					
Gender	Male	Female				
	0.5(1.7)*	Reference				
Age of respondents	Youth (18-35 years)	Middle aged (36-60 years)	>60 years			
	-1.0(0.4)	-0.6(0.5)	Reference			
Marital status	Married	Single	Widowed/widower			
	-0.5(0.6)	-1.5(0.2)*	Reference			
Main source of income	Farming	Employed	Self-employed			
	0.9(2.6)*	0.3(1.3)	Reference			
Education	No formal education	Some primary Education	Completed primary school	Some secondary school	Completed secondary school	Tertiary education
	-1.7(0.2)*	-1.0(0.4)*	-0.5(0.6)	1.2(1.2)	0.5(1.7)	Reference

*p<0.05, R^2 is 52.0 with constant of 212.7 at p<0.05. Values not in brackets are Beta values, those in brackets are Odd ratio. Reference category is a no response

Out of the farmers who indicated they had challenges in yellow maize production, the major limitations they pointed out were low soil fertility, *Striga* weed and poor market for yellow maize (Table 4). Except for *Striga* weed the farmers assigned a high level of impact on all the constraints with emphasis on low soil fertility and poor market for yellow maize.

Table 4. Yellow maize production challenges and their levels of magnitude

Production Constraints	**% respondents**	**% Magnitude**		
		High	**Medium**	**Low**
i. Low soil fertility	71	71	18	11
ii. Striga weed	60	16	46	38
iii. Poor marketing of output	46	85	8	7
iv. Pests and diseases	34	45	32	24
v. Extreme weather	33	57	31	12
vi. Lack of financial resources to purchase inputs	24	54	29	17
vii. High prices of the inputs	20	42	35	23
viii. Lack of access to agricultural extension services	20	48	34	18

ix.	Low technical know-how	19	49	29	22
x.	Unavailability of inputs	17	40	37	24
xi.	Lack of access to credit facilities	17	53	26	21

Except for the challenge of low soil fertility, striga weed and pest/diseases which farmers tried to manage by incorporating coping strategies such as fertilizer application, uprooting and to some extent pesticide applications, farmers did nothing on the rest of the challenges to salvage the situation (Table 5).

Table 5. Coping mechanisms to address challenges faced in yellow maize production

Challenge	Coping mechanisms	%
Low soil fertility	Apply organic or inorganic fertilizer	78
	Intercropping	2
	Did nothing	16
Striga weed	Uprooting/weeding	52
	Deep ploughing with fertilizer application	16
	Herbicide application	13
	Did nothing	11
Pests and diseases	Apply pesticide	47
	Apply Ash	4
	Intercropping/crop rotation	3
	Use of Scarecrow	1
	Burn infected crops	1
	Did nothing	43
Extreme weather	Monitor weather	12
	Timely planting	4
	Replanting	2
	Crop diversification	1
	Drainage during floods	1
	Avoid maize planting during long rains	1
	Did nothing	77
High prices of the inputs	Take loan/borrow	16
	Use local cheaper alternatives	16
	Get handover materials	4
	Did nothing	53
Unavailability of inputs	Take loan/borrow	14
	Use on farm inputs	21
	Getting handouts	7
	Did nothing	58
Lack of financial resources to purchase inputs	Take loan/borrow	33
	Use local cheaper alternatives	6

Lack of access to credit facilities	Nothing	60
	Forming CBO for easy loan access	18
	Take individual loan	8
	Partnership with agricultural NGO's	5
	Did nothing	68
Low technical know-how	Get information from social media	17
	Attend seminars and workshop	18
	Get information from radio	7
	Seek advice from fellow farmers	11
	Did nothing	59
Lack of access to agricultural extension services	Use own knowledge	7
	NGO training/seminars	18
	Get advice from fellow farmers	9
	Get information from internet/radio	5
	Did nothing	59
Poor marketing of output	Home consumption	5
	Selling at off peak season	15
	Did nothing	79

Soil fertility status and farm inputs utilization

Low soil fertility status was reported by 60% of the respondents with half of these being farmers from Kanyamwa Kologi while high and no change in soil fertility status each constituted about 20% of the respondents (Figure 5).

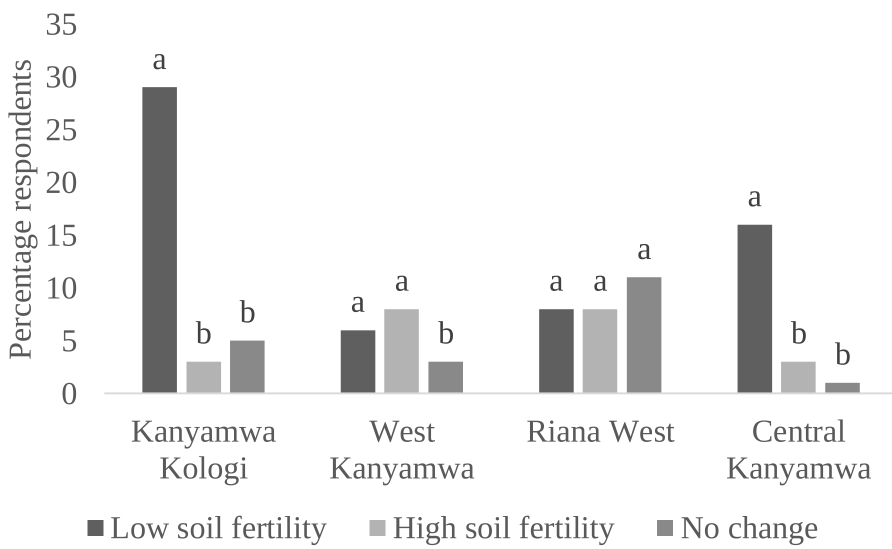

Figure 5. Soil fertility status in Ndhiwa Sub-county, Homa-Bay County. Different letters per attribute indicate significant difference at P<5%

The main indication that the soils were not fertile was low yields reported by 80% of the respondents followed by stunted plants (14%) while 4-7% of the respondents cited complete crop failure, striga weed infestation and yellowing of leaves (Table 6). Low soil fertility levels were attributed to the continuous cultivation and soil erosion. Of the 22% who indicated that their farm had high soil fertility level with corresponding high yields due to fertilizer application, the rest indicated that there was no change in soil fertility levels due to almost similar crops yields that had been obtained over the years which they attributable to their consistent fertilizer application.

Table 6. Soil fertility status indicators and contributors among yellow maize farmers in Homa-Bay County

Soil fertility status	Indicators	% Respondents	Contributors	% Respondents
Low(n=228)	Low yields	7 9 1	Continuous cultivation	35
	Stunted crops	5	Soil erosion	20
	Yellow leaves	7	Striga weed	8
	Striga weed infestation	9	Waterlogging	8
	Complete crop failure	4	Monocropping	8
			Failure/poor fertilizer application	6
High(n=81)	High yields	1 0 0	Fertilizer application	78
			Crop rotation	7
			Intercropping	6
			Ploughing back crop residue	5
			Leaving land fallow for one season	5
No change (n=76)	Same or slight change in yields	1 0 0	Not aware	25
			Fertilizer application	33
			Crop rotation	4
			Striga weed	7
			Monocropping	3

An estimated 31% of the farmers did not apply any agricultural input in their farms. Those who applied either organic or inorganic fertilizers were 40% and 30%, respectively, while there was minimal use of herbicide (3%) and pesticide (5%). For the respondents who applied organic fertilizer it was mainly on farm sourced (80%) from animal wastes with an average amount of 17 kg applied once per cropping season. When it came to usage of maize stover 55% of the farmers indicated that they ploughed back into the soil, however others either allowed in situ livestock grazing (36%) or opted to burn the stover (14%).

Inorganic fertilizer was applied twice per cropping season (86%) at an average rate of 35 kg (SD=27.21). It was sourced mainly from local agrovet shops (88%)

and a non-profit making agricultural organizations (14%).

Yellow maize post-harvest handling practices

The most common method of yellow maize drying was spreading outside in the sun using polythene/manilla sheets as applied by 68% of the farmers while 31% used tarpaulin and only 2% dried on cemented drying yards. There was no respondent drying their maize directly on bare ground or using solar driers. The reasons given for use of manilla/polythene sheets was that it was cheap (n=109, 42%), dries grain faster (n=72, 28%) and easily available (44,17%) while tarpaulin was considered durable (n=28), exists in large sizes (n=21), affordable (n=19), waterproof (n=18), available locally (n=12) and dries maize faster (n=11). Main challenges that the farmers faced with these two methods were feeding by domestic animals and weather changes especially rains which limited the drying process. The farmers coped by restricting livestock entry by fencing the compound or tethering the animals. They also closely monitored the weather and spread the grain to dry only when it was sunny. They were also forced to quickly remove the grains in case of unexpected rains.

Almost all the respondents (97%) stored their yellow maize. The most used storage containers were polypropylene bags by 87% of the farmers with a few using baskets (5%) and drums (4%). Reasons for the popular use of polypropylene bags was because it was affordable (43%), readily available (19%), durable (16%) and portable (16%).

On the manner of storage, 90% of the respondents stored yellow maize on raised platform in their houses for a period of up to 3 months/year with 57% of the respondents storing their yellow maize with other crops such as beans (48%) groundnuts (15%) and white maize (6%). Main causes of losses during storage were pests (74%), molds (9%), theft and bad weather each constituting 4%. When it came to spoilt or molded yellow maize, 67% of the respondents resorted to feeding it to livestock/poultry, especially chicken, others (5%) used it for human consumption while 12% sold it to *chang'aa* brewers and only 11% discarded it.

Yellow maize consumption pattern

About 95% of the respondents preferred to consume yellow maize compared to white maize. Reasons given in order of priority were due to its taste/sweetness (60%), it is economical since it is bulky requiring little amount during cooking, providing quick satiety and being affordable (36%), it is nutritious boosting immunity (31%), its availability due to its hardiness against biotic and abiotic stresses (6%) and family preference (2%). In terms of maturity, yellow maize took 3 months to harvest with vast majority (99%) growing yellow maize mainly for home consumption. They also sold directly to other consumers 41%, while 4% sold to farmers as seed hence there was hardly any processing.

Yellow maize was mainly consumed in the form of ugali (stiff porridge) (97%), boiled maize (38%), roasted maize (27%), porridge (12%) and Nyoyo (meal consisting of mixed maize and beans) (12%). Mid-December to January and from mid-May to June were periods during the year indicated to have plenty of yellow maize to consume since this was at the peak of harvest after the short and long rain seasons, respectively. On the other hand, the months of March, April to mid-May and from August to mid-December, totaling to 7 months, were considered as having low yellow maize for consumption as most households had run out of their harvested stock (Figure 6). Frequency of yellow maize consumptions in most households was twice a day (77%) and once daily (16.4%) with majority considering the crop as most important (49%) or important (47%) in assuring household food security. When consuming yellow maize, the following were the accompanying legumes: Common beans (78%), green grams (21%), cowpea leaves (27%) and cowpeas grains (7%) with major sources being from own production (59%) and purchase from local market (37%). On ways of improving yellow maize production, farmers recommended that they be provided with incentives or financial aid to access inputs especially fertilizer and pesticides/herbicides more for management of striga weed.

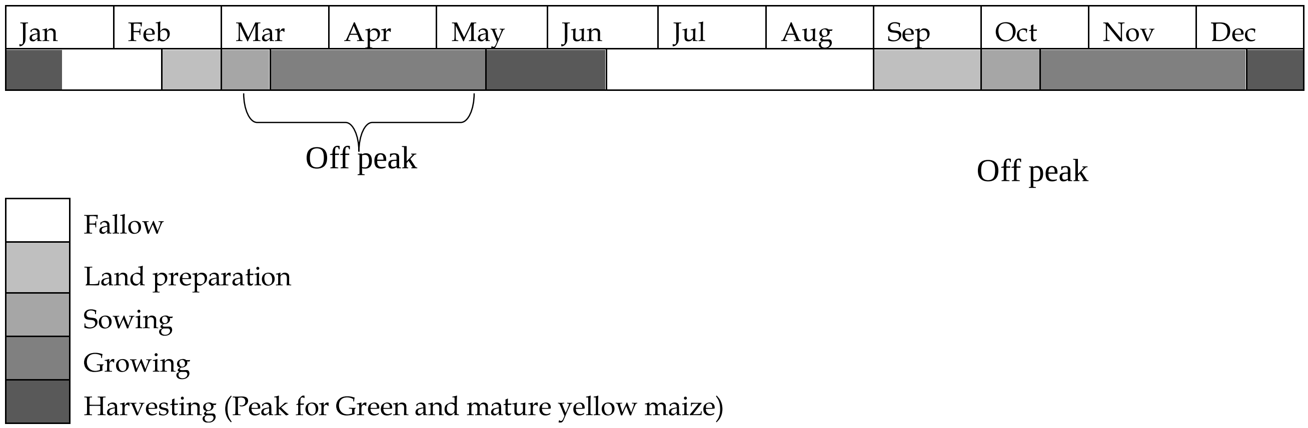

Figure 6. Yellow maize yearly production cycle indicating peak and off seasons

Discussion

Socio-demographic characteristics

There was no gender disparity as both genders were involved in yellow maize production with majority of the respondents being married. Since farming activities are manually done basically using family labor married people were at an advantage as they tend to support each other while also engaging the children (Rapsomanikis, 2015). The yellow maize farmers were mainly youths (18-35 years) and middle-aged groups (35-60 years) which indicates that yellow maize production in this area was done by people in their productive age. This is in contrast with the notion that farming is mainly practiced by the older retired population of over 60 years of age (Birch, 2018). This is probably due to high rate of unemployment even among educated youths and the urgency to meet basic food needs which may have left them with limited options but to engage in agriculture. The engagement of young people could be advantageous to improving rural agricultural productivity since unlike the older people who tend to be conservative, they tend to be more dynamic and are also able to adapt to new technologies or innovations. However, to ensure their total engagement, the enterprise must be viable and profitable to guarantee decent livelihood.

Land ownership and tenure

Majority of the land used for yellow maize production were on average 0.4 ha in size and had title deeds which could have either been inherited or purchased. Our results are confirmed by the Homa-Bay County integrated development plan of 2018-2022, (CIDP, 2018), which showed that 85% of lands have title deeds, however, the average land holding size was cited to be 3 acres. This indicates that although individual land ownership offers a form of land tenure security, increased human population pressure has resulted in land fragmentation to uneconomical levels with no possibility for inheritance (Birch, 2018; NLC, 2021). As a result of this, some farmers have resorted to leasing land to increase farming acreage while others opted to engage in other off-farm activities. Despite this, the results show that the main source of occupation was farming though there is high probability that at least one member of a family had off-farm sources of income such as working as agricultural laborers in other bigger farms or in agricultural industries, to supplement their home needs. Since these are agriculture related, they must have viewed them as farming occupation.

Yellow maize production systems

Yellow maize yield of less than 1 t/ha attained by majority of farmers is dismal compared to optimal levels of 6 t/ha. This raises concerns considering that this is a mid-altitude region with warmer climate and shorter maize growing season hence has a potential to yield better to meet household daily dietary consumption needs throughout the year. Both sole and intercropping systems of production were employed in most farms in the production of yellow maize. Some farmers engaged in polyvariety which involved cultivation of yellow maize together with other maize varieties which were either local landraces or improved white maize varieties. They also cultivated other crops especially legumes such as beans and groundnuts with production of these crops majorly indicated to be for home consumption. This is seen as a strategy to minimize risks and to also try and secure maximum possible yields especially maize.

Farmers have limited knowledge on the recommended spacing for maize as majority of the farmers constituting 90% used heterogeneous spacing that was either below or beyond the recommended arrangement of 75 cm by 30 cm as suggested by Esilaba et al. (2021). This would result to high or low plant density leading to unwarranted competition and limited resource utilization with great impact on crop yields. This is an indication that farmers had limited access to information resulting in poor farming practices that did not adhere to good agronomic practices recommended for improved maize production. There is need for extensive extension services coupled with education and training on basic crop agronomic practices.

Constraints in yellow maize production

Farmers indicated that they were facing several constraints in yellow maize production, key bottleneck being lack of quality seeds as informally seed system was the only supply channel for yellow maize seeds. The other alternative was for farmers to seek seed from the local market and this was done mainly during crisis when their on-farm seed stock was depleted. This finding concurs with Wambugu et al. (2012) who found majority of the maize farmers in Western Kenya to be heavily reliant on farmer own recycled seeds. The yellow maize variety grown by the farmers originally came as food aid and some were used as seeds and indigenized by undergoing years of selection by the farmers themselves with each harvest, therefore, a cultural heritage to the people and highly valued providing them with sense of ownership (Hebinck *et al.,* 2015). Despite the high yielding potential of improved maize varieties only 17% of farmers were involved in their production signaling their low uptake in the region. These farmers have stuck to growing only local open pollinated maize varieties or growing both improved with local maize landraces especially yellow maize that is predominant in most of these farms. Even though there are negative concerns due to informal seed sourcing, such as loss of seed quality responsible for low yields, the critical role the informal seed sector plays cannot be overlooked as it is currently the only option that these farmers have of ensuring yellow maize seed security that currently is not being met by the formal seed sector. It therefore needs technical and financial support to ensure high yielding quality seed supply that meet local farmers' needs and preferences.

The other major constraint is low soil fertility. Farmers could decipher this problem due to reduced harvest they obtained compared to previous years and with some using the term '*the soil is tired*'. This was mainly due to their poor practice of applying little or no agricultural inputs attributed mainly to high cost of inputs and low purchasing power. There are those who deemed fertilizer application especially inorganic fertilizers as unnecessary and had a distorted belief that they actually poison the soil making it unproductive. These could be the probable cause why there were very few farmers willing to take loans to overcome the challenge of input accessibility and affordability. This is in contrast to previous study by Sheahan et al. (2013) who found that 90% of farmers in Western Kenya used fertilizer on their maize fields. This may apply to farmers cultivating improved varieties and usually the highly preferred white maize which must be complemented with inorganic fertilizer application to enhance the inherent seed quality for optimal yields to be realized (Munyiri, 2020). The low yellow maize yield performance demand measures to be taken to restore the limited but important soil nutrient reserves by educating the farmers and encouraging sustainable integrated soil fertility management that have multiple long term benefits (Kihara *et al.,* 2015; Mucheru-Muna *et al.,* 2014).

Although in this study samples of yellow maize were not taken to determine the vitamin A content there is high probability that the low soil fertility status being experienced could also result in nutrient deficiencies especially in regards to Vitamin A content in yellow maize. This is evident from the findings by (Laurie et al. (2012) who found that the quality of crop in terms of essential nutrients composition such as Vitamin A component to be significantly influenced by the soil nutrient levels. In their study, Beta-carotene (a precursor for vitamin A) content of orange fleshed sweet potato was found to be twice and four times higher at 50% and 100% recommended fertilizer application rate compared to no fertilizer application.

This affirms the important role soil fertility status play in ensuring human nutrition, health and wellbeing hence the need of ensuring its proper maintenance and management. To ensure that consumers of yellow maize benefit from desirable attributes especially in terms of vitamin A content, there is need for nutritional assessment of yellow maize variety grown in this region. This will also help provide important nutritional information critical for promotion of the crop.

Another common practice among farmers in all the wards was continuous maize cultivation, known not only to reduce soil fertility but encourage build-up of pest and diseases considering the poor use of herbicides and pesticides amongst the respondents. These poor agronomic practices have far reaching consequences which include prevalence of striga weed in the region (Silberg *et al.,* 2019). This is because most farms were infested with striga weed locally named as *Kayongo* and was commonly managed by employing convectional practice involving roguing/ uprooting usually when the weed has developed and established even in some instances flowered. This practice is not effective to curb this menacing weed as it is done after the weed has emerged from the soil, a stage considered too late to warrant the effort as great crop damage would have already occurred with detrimental effect on yields (Obilana & Ramaiah, 1992). Tackling this menacing weed involves coating seeds with herbicide to kill the germinating weed before it parasitizes the maize (Abayo *et al.,* 1998). Most farmers are, however, resource constrained and are not able to purchase the herbicide hence their cry for incentives to be able to access herbicides to manage the weed at an early stage. Other measures to manage the weed that should be encouraged to ensure yellow maize yield improvement include soil fertility enhancement especially with organic fertilizer and practicing of crop rotation or intercropping especially with legumes (Kuchinda *et al.,* 2003; Obilana & Ramaiah, 1992).

Yellow maize also had very low marketability as also confirmed by De Groote & Kimenju (2012) that showed low preference for yellow maize among maize consumers and thus suffering from lean market and less trading. Carletto et al. (2017) indicates that agricultural commercialization is the pathway out of poverty for smallholders. The poor market accessibility, however, limits commercialization of yellow maize restricting it to subsistence and as such there is barely any returns generated hindering investment in agricultural inputs such as seeds and fertilizer or any other effort that would otherwise have boosted production. This also makes the crop to be unattractive, non-competitive and of little economic importance hence neglected and abandoned with limited formal development especially by people in government and research fraternity. Widespread popularization and promotion are needed to create awareness among the wider population in order to increase its value and acceptance hence rise in consumer and market demand.

Yellow maize post-harvest handling

Open air sun drying with grain spread as a thin layer on polythene sheet laid on the ground, was the standard practice most relied upon as it was simple and cheap and favored by tropical climatic conditions. There are, however, notably risks with this method as farmers decried livestock insecurities as they would feed on the grain if left unattended and adverse weather conditions which required regular monitoring making this method to be laborious and time consuming. To minimize any further yields losses after harvesting and ensure long-term storage it is recommended that maize be dried to 13.5% moisture content and accompanied by proper handling and storage (De Groote *et al.,* 2021). However, in the open air sun drying method there are high chances of suboptimal grain drying especially when harvesting is done during rainy season resulting in molds and exposing the grain to aflatoxin contamination and insect damage. Many respondents (84%) believed molded and discolored yellow maize to still be safe for consumption and, therefore, rather than discard; they fed to livestock especially poultry, consumed directly by further mixing with good grains to mask the off flavor or sold to chang'aa brewers. Similar practices were observed by Koskei et al. (2020) in regions of Rift Valley and Lower Eastern Kenya, although the percentage was low at 3.5%. With this high percentage consuming molded maize directly or indirectly, cases of aflatoxin exposure could be high and require further investigation. This is confirmed by the findings of Mahuku et al. (2019) who studied aflatoxin contamination of maize in Eastern and South western Kenya which included Homa-Bay county, the same region targeted in this study. The study showed maize in the two regions to have exceeded the maximum allowable limit of aflatoxin B_1 contamination (5µg kg^{-1}) for human consumption. This poses food safety risk in this region with significant threat to health and lives of people who are dependent on this crop as their staple food due to aflatoxin poisoning. Ingestion of aflatoxin whether high or low can overtime lead to cancer, liver damage, stunted growth and development, malnutrition due to limited nutrient absorption, suppressed immunity with increased severity in infections and even death (Lewis *et al.,* 2005; Wu *et al.,* 2011). Another concern during grain sun drying is the possible compromise in the carotenoid nutrient content due to its susceptibility to elements such as light and oxygen which maize is generally exposed to when employing the traditional sun drying method (De Moura *et al.,* 2015; Manjeru *et al.,* 2017). Awareness needs to be created on dangers of consuming molded maize and alternative post-harvest management practices and technology that are simple and cost effective such as use of solar driers need to be harnessed in order to reduce on food wastages and losses. This will go a long way in minimizing losses when viewed in the context of the impacts it will have on the shelf life, safety and quality of yellow maize especially in regards to its promising potential of delivering vitamin A for improved human nutrition and health.

Most farmers used polypropylene bags for their dried yellow maize grains and stored them in their residential homes together with other crops posing a risk of cross contamination. The study by Midega et al. (2016) is not in tandem with our findings as it showed that most Homa-Bay respondents stored their grains in traditional granaries. The traditional granaries have been abandoned by most communities due to a number of reasons. Some view it as old system while others see it as a security threat since it attracts maize thieves in the homestead. The low yellow maize yields have resulted to short storage period with hardly enough to meet household needs providing another probable reason for lack of specialized storage structures.

Pests was a major concern during grain storage with use of pesticide being also very low due to limited finances as mentioned earlier which is consistent with studies by (Midega *et al.,* 2016). Some farmers opted to use traditional method involving coating the grains with ash to protect against pest attack. The use of ash is supported by past studies that have shown its effectiveness as a pesticide (Boeke *et al.,* 2001; Deng *et al.,* 2009; Goudoungou *et al.,* 2015; Hakbijl, 2002; Mutsotso *et al.,* 2011). Generally, farmers in this region have not been exposed to use of hermetic bags for grain storage mainly due to high cost implications putting them out of reach of most resource constrained farmers.

Yellow maize attributes and consumption patterns

Farmers were attracted to grow local yellow maize variety as they perceived it to be hardy (tolerant to drought, pests and striga weed), and even able to out yield improved white maize in poor input and marginal soil conditions that most farms usually operate under. This could be another probable cause for the low input application that was observed among the yellow maize farmers. The crop is early maturing taking about three months to mature, making this an ideal crop to evade adverse weather stresses in an agricultural system that is majorly rain-fed. It is therefore considered to have inherent climate resilience with low input requirements hence can be deployed as among key climate change adaption strategies and as means to safe guard against environment degradation. The traditional yellow maize is also said to be bulky requiring a little amount to cook a huge portion of the most favored meals like stiff porridge (ugali) dish and quickly satisfies unlike white maize varieties. Little amount of yellow maize flour is therefore used to feed the entire household hence very economical. This has resulted to it being a daily household food consumed in a variety of dishes an indication of the important role it plays in assuring household food security. There was also an indication of it being used in making local traditional beer.

The yellow color of maize is among the least considered attribute given by the farmers and this could have been influenced by them being accustomed to consuming it and are therefore unperturbed by the color. This, however, is not the case with the wider population who find the yellow color among the reasons deterring them from consuming yellow maize (De Groote & Chege, 2008; Kimenju *et al.,* 2005). Unlike white maize it has Vitamin A, a nutritious attribute that is important for improved nutritional and health status especially to children and women with a unique sweet taste mainly when eaten as roasted maize hence most preferred by the people (Hebinck *et al.,* 2015; Muzhingi *et al.,* 2011). This can be an avenue of promotion especially among young children by introducing it in the pre-school feeding programmes and among road side maize roasting vendors in the urban and peri-urban areas to increase access of yellow maize to the wider population.

This study only targeted yellow maize farmers and the main feature observed was that production was specialized for home consumption. The expectation therefore is that these people should not be suffering from vitamin A deficiency (VAD) as yellow maize can provide considerable levels of nutrients required to combat VAD among the population. This has been confirmed through the experimental study by Muzhingi et al. (2011) that showed food based approach involving yellow maize consumption to have potential to increase the serum retinol concentration and a large increase in β-carotene concentration. However, a study by Othoo et al. (2014) showed that pregnant women who attended Ndhiwa Sub-District Hospital located in West Kanyamwa Ward did not meet the recommended dietary allowance for Vitamin A despite their daily dietary intake constituting mainly maize. The type of maize whether white or yellow was, however, not indicated. The other probable cause to this disparity could be attributed to yellow maize low yields and seasonality due to rainfall dependence. This could potentially limit adequate vitamin A intake considering that in most households the harvested stock only lasted for three months/year. Farmers have then to turn from producers to maize buyers during the lean seasons to fill the food gap Koskei et al. (2020) with the only available option being the carotene devoid white maize as they had nowhere else to source for yellow maize. This confirms the low preference and lack of involvement in cultivation of yellow maize among the wider community, hence the need to ensure its availability and acceptability especially to the vulnerable customers. Improved production of this crop is therefore essential to ensure adequate household food supply and even surpluses for sale to safeguard against Vitamin A deficiency.

The farmers consider yellow maize as an ideal crop as there was no mention of any negative attribute that was given, despite the low yields that we observed and the low market value that has limited farmers involved in its production to only home consumption. This means that to the farmers, yields and marketability were not major factors in choosing this variety as they were among the least considered traits of importance. Although this outcome was rather unexpected, these farmers consider this crop as a safety net against risks of crop failure coupled with its ability to fit well with their socio-economic status considering the marginal and stressful conditions (low inputs, poor soils, adverse weather conditions, pest and disease incidences) that the crop was subjected during production in the farms. The bottom line is that they are at least able to put food on the table using very little resources which would otherwise not have been tenable with improved maize varieties grown under the similar conditions. Its continued cultivation could also be viewed as a means to fulfilling and preserving their cultural and social identity as they have been known to grow yellow maize for generations. This crop has an upper advantage over white maize as it is nutritious, economical at both production and consumption levels while also being stress tolerant and stress averse contributing to its resilience and versatility to local conditions. These merits make this local yellow maize worthy of being supported and explored among the communities in the region to help address the food and nutrition security situation and improve household livelihood.

The small land sizes demand that farmers focus on their immediate food needs, hence fodder production was rare as no farmer mentioned their involvement in its production. This means that livestock were mainly kept under extensive system where they were left to fend for themselves especially in the case of poultry or grazed on natural pastures with no or minimal supplementation which usually involves feeding the animals on farm wastes (Ochieng *et al.,* 2013; Onono & Ochieng, 2018). Maize stover is among such by products and is a crop residue usually obtained after harvesting of mature cob. In this study farmers involved in mixed crop and livestock farming reserved dry maize stover as feed for the large animals especially cattle confirming the important role it contributes in the livestock diet (Berazneva *et al.,* 2018). However, the dry stover have little nutritional value and only act to maintain the animal during the dry period (Thorne *et al.,* 2002).

The quality as well as quantity of this feedstuff can be improved by using dual purpose grain legume fodder residues such as groundnut, cowpea and soybean produced in an intercropping system (Akakpo *et al.,* 2020; Muoni *et al.,* 2019). Farmers can as well practice agroforestry through planting tree legumes and fruit trees to achieve improved animal performance and ensure nutritious food supply. Households will then be able to utilize livestock or livestock products for instance as food or provide draught power and manure for crop production or sell the surplus uplifting health status and livelihoods of the rural population (Baudron *et al*., 2015; Belel *et al.*, 2014). Farmers wholly involved in crop farming opted to plough maize stover back to the soil, a practice shown to enhance soil fertility, moisture and biodiversity while reducing soil erosion thereby enhancing soil productivity (Kiboi *et al.*, 2019). Despite its multiple use in the farm, it is surprising that some farmers opted to burn maize stover which should be discouraged as this result in loss of organic matter input against a background of declining and low soil fertility status.

Conclusion

Smallholder farmers in Ndhiwa, Homa-Bay County consider local yellow maize to be of importance due to its superior agronomic and consumer qualities compared to the conventional white maize which provides opportunity that can be tapped to enhance food and nutrition security within the region. However, this study highlights various constraints of yellow maize production; it is mainly rain-fed with cultivation carried out in small scale farms with low soil fertility and infested with striga weeds, use of unsustainable agricultural practices under low input agriculture application and poor seed system. The little grain harvest is also subjected to poor postharvest drying and storage with low commercialization and limited sources of information. This has contributed to poor performance and utilization that has limited its production to only home consumption with only the wastes (stover and molded grains) used as animal feed. The potential of this crop is therefore grossly under exploited and overcoming these challenges through research, capacity building and mainstreaming its production could be among the pathways that can be used to develop the yellow maize value chain in the region.

References

Abayo, G. O., English, T., Eplee, R. E., Kanampiu, F. K., Ransom, J. K., & Gressel, J. (1998). Control of parasitic witchweeds (Striga spp.) on corn (*Zea mays)* resistant to acetolactate synthase inhibitors. *Weed Science*, *46*(4), 459–466. https://doi.org/10.1017/s0043174500090901

Adavachi, W. M. (2017). *The role of fermented maize-based products on nutrition status and morbidity of children 6-59 months old in Western Kenya*. University of Nairobi.

Aguk, J., Onwonga, R., Chemining'wa, G., Jumbo, M., & Abong, G. (2021). Enhancing yellow maize production for sustainable food and nutrition security in Kenya. *East African Journal of Science, Technology and Innovation*, 2, 1–24.

Akakpo, D. B., de Boer, I. J. M., Adjei-nsiah, S., Duncan, A. J., Giller, K. E., & Oosting, S. J. (2020). Evaluating the e ffects of storage conditions on dry matter loss and nutritional quality of grain legume fodders in West Africa. *Animal Feed Science and Technology*, *262*. https://doi.org/10.1016/j.anifeedsci.2020.114419

Baudron, F., Sims, B., Justice, S., Kahan, D. G., Rose, R., Mkomwa, S., Kaumbutho, P., Sariah, J., Nazare, R., Moges, G., & Gérard, B. (2015). Re-examining appropriate mechanization in Eastern and Southern Africa: two-wheel tractors, conservation agriculture, and private sector involvement. In *Food Security* (Vol. 7, Issue 4). https://doi.org/10.1007/s12571-015-0476-3

Belel, M. D., Halim, R. A., Rafii, M. Y., & Saud, H. M. (2014). Intercropping of Corn With Some Selected Legumes for Improved Forage Production: A Review. *Journal of Agricultural Science*, *6*(3), 48–62. https://doi.org/10.5539/jas.v6n3p48

Berazneva, J., Lee, D. R., Place, F., & Jakubson, G. (2018). Allocation and Valuation of Smallholder Maize Residues in Western Kenya. *Ecological Economics*, *152*, 172–182. https://doi.org/10.1016/j.ecolecon.2018.05.024

Birch, I. (2018). *Agricultural productivity in Kenya : barriers and opportunities*. https://assets.publishing.service.gov.uk/media/5c70028ee5274a0ecbe9a1c2/483_Agricultural_Productivity_in_Kenya_Barriers_and_Opportunities.pdf

Boeke, S. J., Loon, J. J. A. van, Huis, A. van, Kossou, D. K., & Dicke, M. (2001). The use of plant material to protect stored leguminous seeds against seed beetles: a review. In L. J. G. van der

Maesen, ir. I. Bos, & W. Backhuys (Eds.), *Laboratory of Entomology, Wageningen University,* (2001st–3rd ed.). Backhuys Publishers.

Carletto, C., Corral, P., & Guelfi, A. (2017). Agricultural commercialization and nutrition revisited: Empirical evidence from three African countries. *Food Policy*, *67*, 106–118. https://doi.org/10.1016/j.foodpol.2016.09.020

CIDP, H. B. (2018). *Homabay County government second county integrated development plan 2018- 2022* (Vol. 2022). http://www.homabayassembly.go.ke/wp-content/uploads/bsk-pdf-manager/2018/05/HB-draft5-CIDP-2018-2022-15-5-2018.pdf

De Groote, H., & Chege, S. (2008). Comparing consumer preferences for color and nutritional quality in maize : Application of a semi-double-bound logistic model on urban consumers in Kenya. *Food Policy*, *33*, 362–370. https://doi.org/10.1016/j.foodpol.2008.02.005

De Groote, H., Githinji, P. G., Munya, B. G., & Ricker-Gilbert, J. E. (2021). Economics of open-air sun drying in the maize value chain of Kenya. *Journal of Agriculture and Food Research*, *5*, 100185. https://doi.org/10.1016/j.jafr.2021.100185

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

De Moura, F. F., Miloff, A., & Boy, E. (2015). Retention of Provitamin A Carotenoids in Staple Crops Targeted for Biofortification in Africa: Cassava, Maize and Sweet Potato. *Critical Reviews in Food Science and Nutrition*, *55*(9), 1246–1269. https://doi.org/10.1080/10408398.2012.724477

Deng, A., Ogendo, J., Owuor, G., Bett, P., Omolo, E., Mugisha-Kamatenesi, M., & Mihale, J. (2009). Factors determining the use of botanical insect pest control methods by small-holder farmers in the Lake Victoria basin , Kenya. *African Journal of Environmental Science and Technology*, *3*(May), 108–115. https://doi.org/10.5897/AJEST09.034

Ekpa, O., Palacios-rojas, N., Kruseman, G., Fogliano, V., & Linnemann, A. R. (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*(January), 48–56. https://doi.org/10.1016/j.gfs.2018.03.007

Esilaba, A. O. e. al. (2021). *KCEP-CRAL Maize Extension Manual* (L. W. Esilaba, A.O., D. Nyongesa, M. Okoti, M. Otipa & Compiling (eds.)). Kenya Agricultural and Livestock Research Organization, Nairobi, Kenya. https://www.kalro.org/files/kcep/Maize-Extension-Manual.pdf

FAO. (2020). *FAOstats*. http://www.fao.org/faostat/en/#data/QC

Fisher, L. D. (1998). Self-Designing Clinical Trials. *Statistics in Medicine*, *17*, 1551–1562.

Goudoungou, J. W., Elias Nchiwan, N., Dieudonné, N., Christopher, S., Adler, C., & Nukenine Elias Nchiwan, C. (2015). Efficacy of diatomaceous earth and wood ash for the control of *Sitophilus zeamais* in stored maize. *Journal of Entomology and Zoology Studies JEZS*, *3*(35), 390–397.

Hakbijl, T. (2002). The traditional, historical and prehistoric use of ashes as an insecticide, with an experimental study on the insecticidal efficacy of washed ash. *Environmental Archaeology*, *7*(June 2000), 13–22. https://doi.org/10.1179/env.2002.7.1.13

Hebinck, P., Mango, N., & Kimanthi, H. (2015). Local maize practices and the cultures of seed in Luoland , West Kenya. In *Cult. Sustain. Reg. Dev* (Issue August 2015, pp. 206–218).

Kiboi, M. N., Ngetich, K. F., Fliessbach, A., Muriuki, A., & Mugendi, D. N. (2019). Soil fertility inputs and tillage influence on maize crop performance and soil water content in the Central Highlands of Kenya. *Agricultural Water Management*, *217*, 316–331. https://doi.org/10.1016/j.agwat.2019.03.014

Kihara, J., Tamene, L. D., Massawe, P., & Bekunda, M. (2015). Agronomic survey to assess crop yield , controlling factors and management implications : a case-study of Babati in northern Tanzania. *Nutrient Cycling in Agroecosystems*, *102*, 5–16. https://doi.org/10.1007/s10705-014-9648-3

Kimenju, S. C., Morawetz, U. B., & De Groote, H. (2005). Comparing Contingent Valuation Method , Choice Experiments and Experimental Auctions in soliciting Consumer preference for maize in Western Kenya : Preliminary results. *African Econometric Society 10th Annual Conference of Econometrics*, *January*, 1–24.

KNBS. (2019a). *Enhanced Food Balance Sheets for Kenya 2014-2018 Results* (Issue May). https://www.afdb.org/sites/default/files/documents/publications/food_balance_sheets_kenya_full_report.pdf

KNBS. (2019b). *2019 Kenya Population and Housing census Vol. 1: Population by County and Sub-county: Vol. I* (Issue November). https://housingfinanceafrica.org/app/uploads/VOLUME-I-KPHC-2019.pdf

Koskei, P., Bii, C. C., Musotsi, P., & Muturi Karanja, S. (2020). Postharvest Storage Practices of Maize in Rift Valley and Lower Eastern Regions of Kenya: A Cross-Sectional Study. *International Journal of Microbiology*, *2020*. https://doi.org/10.1155/2020/6109214

Kothari, C. R., & Garg, G. (2014). *Research Methodology: Methods and techniques* (Third). New Age International Publishers.

Kuchinda, N. C., Kureh, I., Tarfa, B. D., Shinggu, C., & Omolehin, R. (2003). On-farm evaluation of improved maize varieties intercropped with some legumes in the control of Striga in the Northern Guinea savanna of Nigeria. *Crop Protection*, *22*, 533–538.

Kuhnen, S., Menel Lemos, P. M., Campestrini, L. H., Ogliari, J. B., Dias, P. F., & Maraschin, M. (2011). Carotenoid and anthocyanin contents of grains of Brazilian maize landraces. *Journal of the Science of Food and Agriculture*, *91*(9), 1548–1553. https://doi.org/10.1002/jsfa.4346

Laurie, S. M., Faber, M., van Jaarsveld, P. J., Laurie, R. N., du Plooy, C. P., & Modisane, P. C. (2012). β-Carotene yield and productivity of orange-fleshed sweet potato (*Ipomoea batatas L. Lam*.) as influenced by irrigation and fertilizer application treatments. *Scientia Horticulturae*, *142*(March),180–184. https://doi.org/10.1016/j.scienta.2012.05.017

Lewis, L., Onsongo, M., Njapau, H., Schurz-Rogers, H., Luber, G., Kieszak, S., Nyamongo, J., Backer, L., Dahiye, A. M., Misore, A., DeCock, K., & Rubin, C. (2005). Aflatoxin contamination of commercial maize products during an outbreak of acute aflatoxicosis in eastern and central Kenya. *Environmental Health Perspectives*, *113*(12), 1763–1767. https://doi.org/10.1289/ehp.7998

Luedeling, E. (2011). *Climate Change Impacts on Crop Production in Busia and Homa Bay Counties , Kenya*. http://www.eikeluedeling.com/uploads/3/1/8/4/3184740/2011_luedeling_acci_climate_modelling_icraf_11-11.pdf

Mahuku, G., Nzioki, H. S., Mutegi, C., Kanampiu, F., Narrod, C., & Makumbi, D. (2019). Pre-harvest management is a critical practice for minimizing aflatoxin contamination of maize. *Food Control*, *96*, 219–226. https://doi.org/10.1016/j.foodcont.2018.08.032

Manjeru, P., Van Biljon, A., & Labuschagne, M. (2017). The development and release of maize fortified with provitamin A carotenoids in developing countries. *Critical Reviews in Food Science and Nutrition*. https://doi.org/10.1080/10408398.2017.1402751

McCann, J. C. (2005). *Maize and Grace: Africa's Encounter with a New World Crop, 1500–2000* (Vol. 2). Harvard University Press.

Midega, C. A. O., Murage, A. W., Pittchar, J. O., & Khan, Z. R. (2016). Managing storage pests of maize: Farmers' knowledge, perceptions and practices in western Kenya. *Crop Protection*, *90*, 142–149. https://doi.org/10.1016/j.cropro.2016.08.033

MoALF. (2016). *Climate Risk Profile Homa Bay County*. https://cgspace.cgiar.org/bitstream/handle/10568/80450/Homa Bay_Climate Risk Profile.pdf

Mucheru-Muna, B. M., Mugendi, D., Pypers, P., Mugwe, J., U, J. K., Vanlauwe, B., & Merckx, R. (2014). Enhancing maize productivity and profitability using organic inputs and mineral fertilizer in Central Kenya small-hold Farms. *Expl Agric.*, *50*, 250–269.

https://doi.org/10.1017/S0014479713000525

Mulungu, K., Kuntashula, E., & Simpungwe, E. (2018). Effect of Participatory Rating on Choice of Vitamin A Fortified Maize Varieties. *SSRN Electronic Journal*, 1–28. https://doi.org/10.2139/ssrn.3251705

Munyiri, S. (2020). Opportunities for Quality Seed Production and Diffusion through Integration of the Informal Systems in Sub-Saharan Africa. *Prime Archives in Agricultural Research*, 1–20. https://doi.org/10.37247/paar.1.2020.19

Muoni, T., Barnes, A. P., Öborn, I., Watson, C. A., Bergkvist, G., Shiluli, M., & Duncan, A. J. (2019). Farmer perceptions of legumes and their functions in smallholder farming systems in East Africa. *International Journal of Agricultural Sustainability*, *17*(3), 205–218. https://doi.org/10.1080/14735903.2019.1609166

Mutsotso, B., Muya, E., & Roimen, H. (2011). Farmers knowledge, attitudes and practices (KAP) in Embu and Taita benchmark sites before and after below-ground biodiversity project interventions. *Tropical and Subtropical Agroecosystems*, *13*(1), 51–58.

Muzhingi, T., Gadaga, T. H., Siwela, A. H., Grusak, M. A., Russell, R. M., & Tang, G. (2011). Yellow maize with high β-carotene is an effective source of vitamin A in healthy Zimbabwean men 1 – 4. *Am J Clin Nutr*, *94*, 510–519. https://doi.org/10.3945/ajcn.110.006486.510

Muzhingi, T., Langyintuo, A. S., Malaba, L. C., & Banziger, M. (2008). Consumer acceptability of yellow maize products in Zimbabwe. *Food Policy*, *33*, 352–361. https://doi.org/10.1016/j.foodpol.2007.09.003

NLC. (2021). *Effects of Land Fragmentation on Land Use and Food Security* (Issue October). https://www.landcommission.go.ke/media/erp/upload/land_fragmentation_report_6.3.22_final.pdf

Obilana, A. T., & Ramaiah, K. V. (1992). Striga (Witchweeds) in Sorghum and Millet: Knowledge and Future Research Needs. In W. A. . de Milliano, R. . Frederiksen, & G. D. Bengston (Eds.), *Sorghum and millets diseases: a second world review* (pp. 187–201). International Crops Research Institute for the Semi-Arid Tropics.

Ochieng, J., Owuor, G., & Bebe, B. O. (2013). Management practices and challenges in smallholder indigenous chicken production in western Kenya. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, *114*(1), 51–58.

Ogenga, J. O. (2021). Analysis of Seasonal rainfall variability in Rainfed Agriculture in Homa Bay County. *International Journal of Scientific and Research Publications (IJSRP)*, *11*(3), 241–245. https://doi.org/10.29322/ijsrp.11.03.2021.p11132

Onono, J. O., & Ochieng, A. (2018). Review of challenges and opportunities for dairy cattle farming under mixed system of Homa Bay County, Western Kenya. *Journal of Agricultural Extension and Rural Development*, *10*(10), 202–210. https://doi.org/10.5897/jaerd2018.0987

Othoo, D., J, W., & Kuria, E. (2014). Dietary assessment of vitamin A and iron among pregnant. *African Journalof Food ,Agriculture,Nutrition and Development*, *14*(3), 2114–2128.

Poole, N., Bentley, A., Donovan, J., Erenstein, O., Ibba, I., & Palacios, N. (2021). *Food security, nutrition and health: Implications for maize and wheat research and development*. https://www.cgiar.org/research/publication/food-security-nutrition-and-health-implications-for-maize-and-wheat-research-and-development-2/

Ranum, P., Pe˜na-Rosas, J. P., & Garcia-Casal, M. N. (2014). Global maize production , utilization , and consumption. *Ann. N.Y. Acad. Sci. ISSN*, *1312*, 105–112. https://doi.org/10.1111/nyas.12396

Rapsomanikis, G. (2015). *The economic lives of smallholder farmers: An analysis based on household data from nine countries*. http://www.fao.org/3/a-i5251e.pdf

Sheahan, M., Black, R., & Jayne, T. S. (2013). Are Kenyan farmers under-utilizing fertilizer? Implications for input intensification strategies and research. *Food Policy*, *41*, 39–52.

https://doi.org/10.1016/j.foodpol.2013.04.008

Silberg, T. R., Grace, V., Chimonyo, P., Richardson, R. B., Snapp, S. S., & Renner, K. (2019). Legume diversification and weed management in African cereal-based systems. *Agricultural Systems*, *174*, 83–94. https://doi.org/10.1016/j.agsy.2019.05.004

Talsma, E. F., Melse-Boonstra, A., & Brouwer, I. D. (2017). Acceptance and adoption of biofortified crops in low- and middle-income countries: A systematic review. *Nutrition Reviews*, *75*(10), 798–829. https://doi.org/10.1093/nutrit/nux037

Thorne, P. J., Thornton, P. K., Kruska, R. L., L. Reynolds, Waddington, S. R., Rutherford, A. S., & Odero, A. N. (2002). *Maize as food , feed and fertiliser in intensifying crop – livestock systems in East and southern Africa :An ex ante impact assessment of technology interventions to improve smallholder welfare*. ILRI (International Livestock Research Institute) Nairobi, Kenya. https://cgspace.cgiar.org/bitstream/handle/10568/505/MaizeImpactAssessment.pdf;sequence=1

Wambugu, P. W., Mathenge, P. W., Auma, E. O., & A, H. (2012). Constraints to On-Farm Maize (Zea mays L .) Seed Production in Western Kenya : Plant Growth and Yield. *International Scholarly Research*, *2012*, 1–7. https://doi.org/10.5402/2012/153412

Wu, F., Narrod, C., Tiongco, M., & Liu, Y. (2011). *The Health Economics of Aflatoxin : Global Burden of Disease*. https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/124848/filename/124849.pdf