

Research Application Summary

Insights into Mango Productivity: Agronomic Practices, Soil Parameters, and Pest Management in Western Uganda

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Abstract

In Uganda, mangoes rank among the top five most popular and economically significant fresh fruits. Despite concerted governmental efforts to promote mango cultivation through nationwide distribution of planting materials, farmers continue to face significant challenges. Therefore, the primary objective of this research was to assess mango productivity, focusing specifically on agronomic practices, soil conditions, and pest and disease management. The qualitative and quantitative data collected illuminated various pertinent issues. Notably, farmers exhibited specific preferences for particular mango varieties, while notable variations in flower and fruit abortions were recorded among these varieties. Alarming, a significant 90.9% of farmers reported not using fertilizers, indicating potential deficiencies in nutrient management practices. Furthermore, the study highlighted pests and diseases, particularly mango fruit flies and anthracnose, as major impediments to production, with 42.7% of respondents identifying them as critical challenges. Given these insights, it is essential to develop targeted interventions to enhance mango productivity in Uganda.

Keywords: Agronomic practices, Mango productivity, Nutrient management, Pests and Diseases, Western Uganda

Résumé

En Ouganda, les mangues se classent parmi les cinq fruits frais les plus populaires et économiquement significatifs. Malgré les efforts soutenus du gouvernement pour promouvoir la culture de la mangue par la distribution nationale de matériel de plantation, les agriculteurs continuent de faire face à des défis significatifs. Par conséquent, l'objectif principal de cette recherche était d'évaluer la productivité des mangues, en se concentrant spécifiquement sur les pratiques agronomiques, les conditions du sol et la gestion des ravageurs et des maladies. Les données qualitatives et quantitatives collectées ont mis en lumière diverses questions pertinentes. Notamment, les agriculteurs ont montré des préférences spécifiques pour certaines variétés de mangues, tandis que des variations notables dans les avortements de fleurs et de fruits ont été enregistrées parmi ces variétés. De manière alarmante, 90,9 % des agriculteurs ont signalé ne pas utiliser d'engrais, indiquant de potentielles carences dans les pratiques de gestion des nutriments. En outre, l'étude a mis en évidence les ravageurs et les maladies, en particulier les mouches des fruits de la mangue et l'anthracnose, comme des obstacles majeurs à la production, avec 42,7 % des répondants les identifiant comme des défis critiques. Compte tenu de ces aperçus, il est essentiel de développer des interventions ciblées pour améliorer la productivité des mangues en Ouganda.

Mots-clés : Pratiques agronomiques, Productivité des mangues, Gestion des nutriments, Ravageurs et maladies, Ouganda occidental

Introduction

Tropical and subtropical regions are well-known for the abundant cultivation of mangoes (*Mangifera indica* L.) (Zuazo *et al.*, 2019). In 2017, mangoes dominated fruit production, accounting for over half (52%) of the total fruit volume. They surpassed other tropical fruits like pineapples, papayas, and avocados, which made up 28.3%, 14.3%, and 6.3%, respectively (FAO, 2020). Mango cultivation not only provides economic opportunities but also enhances nutrition security for smallholder farmers and consumers (Ddamulira *et al.*, 2019). Mangoes, which are rich in vitamins, minerals, and phytochemicals, offer various health benefits, such as reducing the risk of chronic heart problems (Alila and Rao, 2013). The significance of this fruit is evident from its substantial production increase from 26.5 million tons in 2004 to 47 million tons in 2017 (Nagle *et al.*, 2005; FAO, 2020).

Uganda's horticultural sector is rapidly expanding, with annual export revenues ranging from 29 to 35 million USD. This growth, combined with increased processing capacity, has made mangoes Uganda's most popular fruit (UIA, 2009). While there were virtually no exports in 2008, Uganda's mango exports reached 10,112 tons by 2017 (Dijkxhoorn *et al.*, 2019). Mango cultivation has long been embraced by smallholder farmers across Uganda due to its importance and the country's favorable tropical climate (Wangwe, 2012). However, despite widespread adoption, Uganda lags behind other mango-producing nations like India in terms of yield, primarily due to the cultivation of low-yielding local mango varieties without modern management practices (Acema *et al.*, 2016; Sujata and Ramanjaneyulu, 2016; Ddamulira *et al.*, 2019). Furthermore, the high fiber content in most local mango varieties diminishes their appeal for export and processing purposes (Okoth *et al.*, 2013).

Despite government initiatives like Operation Wealth Creation (OWC) and the National Agricultural Advisory Services (NAADS) facilitating the distribution of nearly 12.7 million citrus and mango seedlings across Uganda (UDC, NAADS, OWC 2016), productivity remains low in many regions. Farmers are eager to cultivate mango trees, but they continue to face challenges such as flower abortion, immature fruit drop, and outbreaks of pests and diseases (Ddamulira *et al.*, 2019). The obstacles to mango productivity vary by agroecological zone, including off-site planting and soil macro and micronutrient deficiencies, which exacerbate stress in trees and increase their susceptibility to pests and fungal diseases (Acema *et al.*, 2016). To address these challenges, this study in western Uganda conducted an assessment of agronomic practices, soil parameters, and pest and disease management strategies to optimize mango productivity in the study districts.

Methodology

The study was conducted between February and November 2020 in the districts of Hoima and Kikuube in Uganda. These districts were selected based on their known interest in the Mango production sector. In total 120 respondents were interviewed using a pre-tested questionnaire. Most survey questions were open-ended to avoid limiting farmers' opinions. Data were collected on farmers' social economic and demographic characteristics, mango performance and production practices as well as preferred value chains. Data were also collected on severity and prevalence and the corresponding management practices of common diseases and pests. Additionally, plots were established in farmer fields and susceptibility of different varieties to pests and diseases was evaluated.

Finally, soil profiles at visited mango farms were characterized focusing on Nitrogen, Phosphorous, Potassium, Organic matter and soil acidity (pH) levels. Interviews were administered in farmers' mango orchards to cross-check farmers' responses regarding the pest and disease status with field observations. The geographic coordinates (latitude, longitude, and elevation) of every farm surveyed were recorded with a handheld global positioning system (GPS).

The collected data were both qualitative and quantitative. The qualitative data from Key Informant Interviews (KIIs) were written into scripts from which thematic analysis was conducted. Household survey data were verified, coded, entered in SPSS software and cleaned for analysis. The analysis mainly involved descriptive statistics including frequencies, percentages, and cross tabulations to describe relationships among different variables. Chi-square test was also used to test for statistical association between variables. Geographic coordinates recorded were used to generate a study area map (Figure 1).

An ordinal regression analysis was used to assess the determinants of mango production. The ordinal regression model is specified as

$$\text{logit}(p) = a_k + b_1X_1 + b_2X_2 + \dots b_kX_k$$

Mango yield per tree data was categorized as either low (<100 fruits per tree per season), moderate (100-399 fruits per tree per season) or high (>400 fruits per tree per season). The predictor variables are a set of variables expected to affect yield based on theoretical association. These include age of the farmer, gender, whether the farmer used inorganic fertilizers, whether the farmer used pesticides, membership to a farmer group, etc.

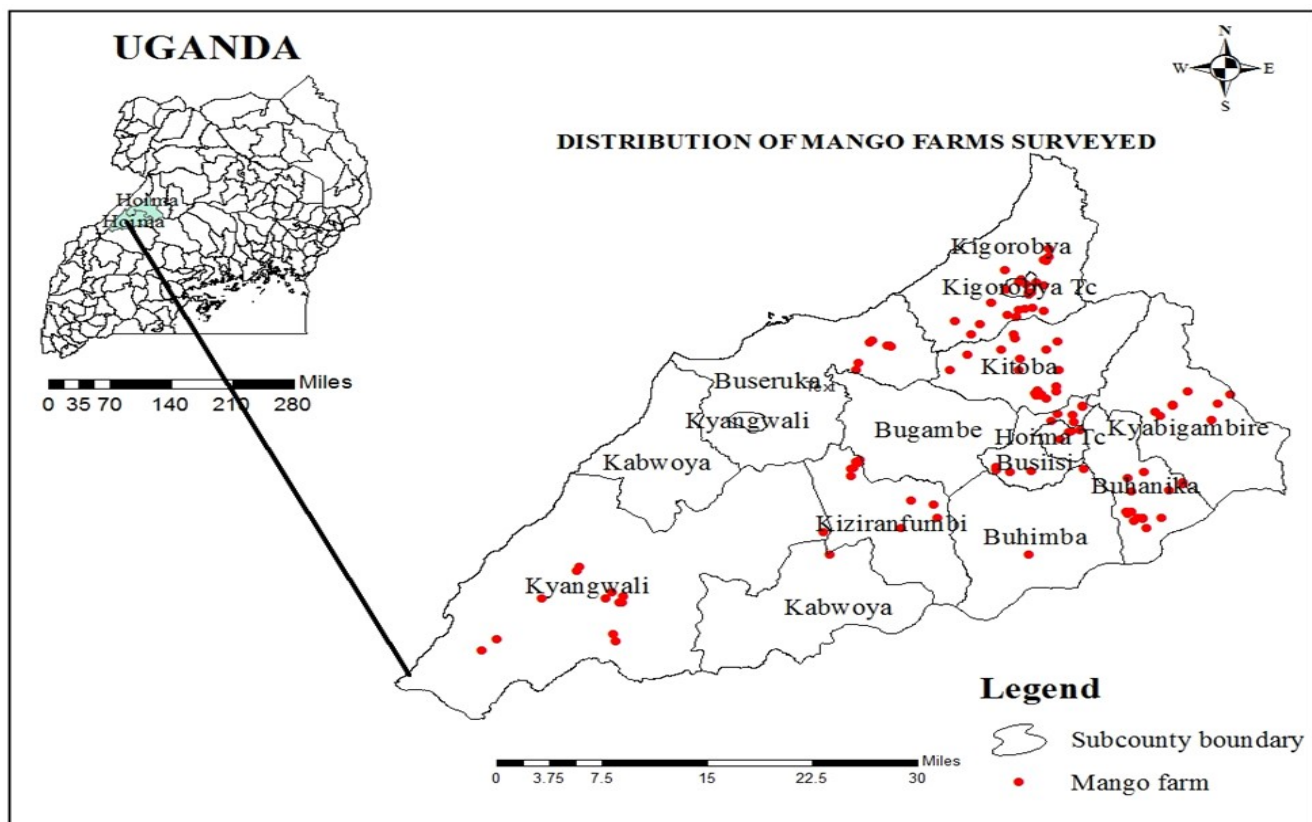


Figure 1. Distribution of farms surveyed in sub-counties of Hoima and Kikuube districts of Uganda

Results

Socio-economic and Demographic characteristics. Overall, 30% of the respondents were women. Most of the mango growers (82.5%) were of the age range of 35 to 69 years while very few farmers were above 69 years (10.8%) or below the age of 35 years (6.7%). Mango farmers in the study area mostly attained primary (34.2%) and secondary (35.5%) education while few had reached tertiary or university levels. Majority of respondents (72.9%) were heads of households and amongst those (86.7%) owned mango orchards. On average the households (64.2%) visited had 5 to 10 members and had farming (80%) as their main source of income. For farmers (84.2%) whose mangoes were already under production, the fruits could only earn them less than a million Uganda shillings (approximately US \$ 300) (93%) per month but most farmers (70%) earned less than a million shillings as their total monthly income. Most of the respondents (44.2%) had spent 5 to 10 years in agricultural work, cultivating on average 10 plus acres of land. Most mango growers (60.8%) got the idea from extension agents and 95.8% of them had alternative source of livelihood besides mango production.

Land tenure and land allocation. Freehold land tenure was the most popular (72.5%) followed customary land (25.8%), with few growers (0.8%) having mailo (titled land). Most farmers (60%) owned >10 acres (approximately 4 hectares) of land and it was not uncommon for growers owning freehold land to allocate bigger portions of (1 to 10 acres) for mango growing as compared to those on customary, mailo and leased land (Table 1).

Table 1. Land tenure and allocation

Land tenure	Owned (acres)				Rented (acres)				Allocated to mangoes (acres)			
	<1	1-4.9	5-9.9	10+	<1	1-4.9	5-9.9	10+	<1	1-4.9	5-9.9	10+
Customary	0	1	12	18	29	2	0	0	11	18	1	1
Mailo	0	0	1	0	1	0	0	0	0	1	0	0
Freehold	0	21	24	42	87	0	0	0	28	56	2	1
Lease	1	0	0	0	0	0	1	0	0	1	0	0

Table 2. Acreage under mango growing in sampled areas in Hoima and Kikuube districts

	District		Total
	Hoima	Kikuube	
Number of mango trees on <100 your farm	58.9% _a	33.3% _b	52.5%
100-799	34.4% _a	60.0% _b	40.8%
800-1599	0.0%	6.7%	1.7%
Not sure	6.7% _a	0.0% _a	5.0%

Each subscript letter denotes a subset of District categories whose column proportions do not differ significantly from each other at 5% significance level

Majority (63%) of farmers had between 1-4.9 acres under mango growing, managing between 100-799 mango trees. The number of trees per farm was higher in Kikuube district.

Factors Influencing Mango Production. The ordinal regression analysis generated a final model using the selected predictors which was a significant improvement on the intercept only model ($p = 0.045$) and the predictors could explain 46.4% of the variation in change in levels of mango production.

Table 3. Regression analysis of the determinants of high mango production

Predictor variables	Estimate	Std. Error	Sig.
Age	0.032	0.029	0.269
Gender (male)	0.754	1.028	0.463
Exotic varieties (Reference Mixed varieties)	1.158	1.300	0.373
Local varieties (Reference Mixed varieties)	-1.050	0.910	0.249
Can you identify mango diseases? (No)	-0.134	0.927	0.885
Can you identify mango pests? (No)	0.343	1.213	0.778
Do you use fertilizer? (No)	-0.474	0.987	0.631
Do you use pesticides? (No)	-2.350	0.929	0.011
Do you belong to a farmer group? (No)	-2.231	1.121	0.047
Do you have access to extension agents? (No)	-1.214	0.931	0.192
Do you use organic inputs? (No)	0.899	0.834	0.281
Pattern of planting (Regular)	-0.363	1.561	0.816

The farmer characteristics which positively determined higher mango production were age of the farmer, gender of the farmer (being male) and growing exotic mango varieties (e.g. Tommy, Kent and Zillate). Strangely even farmers who could not identify mango pests and those who did not use organic inputs were more likely to have higher mango production than those who did. High mango production was negatively affected by not using in-organic fertilizers, not using pesticides, not belonging to a farmer group and having no access to extension agents. Not using pesticides ($p = 0.011$) and not belonging to a farmer group ($p = 0.047$) showed a significant negative effect on the ability to have high mango production. Farmers that only grew local mango varieties were less likely to have a higher production when compared to those that grew a mixture of varieties although the effect of type of mango variety was not statistically significant. Regular planting pattern was also found to negatively affect getting high mango yield when compared to those who planted in a scattered pattern. Regular plant spacing ranged from 3m² to 12m² with about 66.4% of famers using between 3-5m² plant spacing. This spacing is inadequate for proper productivity.

Reasons for mango cultivation. In the study area, mango farmers prioritized growing mangoes for sale over home consumption, and those who grew mangoes for a longer period of time (15+ years) tended to have fewer trees. Most farmers who grow mangoes mostly for sale had only been growing them for a short time, and they have more trees on their farms than those who grow them for home use (Table 4).

Varieties of Mangoes Cultivated and Their Performance. Generally, 94.7% of the mango farmers grew more than one mango variety. A few farmers (16.7%) chose the mango varieties they wanted, while 83.3% waited to receive them from the government (63.9%) and non-governmental organizations (22.7%). Farmers (61.7%) could only recognize mango varieties by their common names. The most grown varieties were Tommy, Kent and Bire while Magada, Ssejjembe, Lunywa and Nyomo were the least encountered, respectively (Table 5). Tommy was ranked the most preferred variety based on its yield, taste, market, early fruiting and shelf life (Table 5). Flower abortion and fruit drop of Tommy, Bire, Kent, Apple and Boribo mango varieties were generally reported to be high while their resistance to pests, diseases and seasonal changes were reported to be low

(Table 5). In general, 200 - 300 fruits were reported per tree per season (23.3%). Few farmers (5.8%) reported an average tree yield of more than 500 fruits, while only 6.7% reported an average tree yield of less than 50 fruits. Generally, fruits are mostly abundant in June and scarce in March (Figure 2).

Table 4. The rationales for mango cultivation, the quantity of mango trees under cultivation, and the duration of involvement in mango cultivation.

Reason	Rank	Years in mango growing	Number of mango trees on farm		
			<100	100 -799	800-1599
Household consumption	Least important	<5years	4	1	0
		5-9.9 years	4	4	1
		10-14.9 years	2	9	0
		15+ years	0	1	0
	Important	<5years	9	8	0
		5-9.9 years	24	14	1
		10-14.9 years	10	9	0
		15+ years	5	2	0
	Most important	5-9.9 years	1	1	
		10-14.9 years	3	0	
		15+ years	1	0	
Sale	Least important	5-9.9 years	1		
		10-14.9 years	1		
		15+ years	1		
	Important	5-9.9 years	5	2	
		10-14.9 years	5	0	
		15+ years	4	0	
	Most Important	5-9.9 years	23	17	2
		10-14.9 years	9	18	0
		15+ years	1	3	0

Production practices. Of the farmers interviewed, 61.8% of the respondents intercropped mangoes with other crops whereas 39.2% had mono-crop orchards. Mangoes were mainly intercropped with bananas (15.1%), beans (15.1%), coffee (14.4%), cassava (11.6%) and maize (9.6%). Farmers reported that inter cropping is the main practice used in ensuring soil fertility (33.5%) (Table 7). Cross-tabulations indicated that mango farms integrated with other crops were associated with higher yields per tree compared to mono-cropped farms. The spacing reported varied widely amongst farmers with the smallest being at 2.5mx2.5m and the largest at 12mx12m. The commonly used spacing regimes were 3mx3m (12.5%), scattered (11.7%) and 8mx8m (10 %). The latter was however associated with better yields of above 400 mangoes per tree while the 2.5mx2.5m was mostly associated with less than 50 fruits per tree. Averagely, weeding, manuring and pruning are undertaken twice a year while spraying is done thrice a year. During harvesting, most farmers (50.8%) harvest both fully and partially ripen mangoes as opposed to only fully ripen (7.5%) or partially ripen (20.8%). Hand picking was the main harvesting method reported (75.8%) while harvesting is mostly done at any time of the day. Most farmers (67.5%) store their harvested mangoes in storage houses as opposed to under tree shades (15%). Wooden boxes were the main packaging material (39.2%) although 26.6% of the respondents do not package harvested mangoes. Pests and diseases were reported as the major production constraints (42.7%).

Table 5. Mango varieties, their preference and selected performance indicators

Mango variety	Preference		Selected Performance indicators						
	Count	Rank	Reasons	Flower abortion	Fruit drop	Resistance to pest and disease	Tolerance to seasonal changes	Fruit bearing behavior	Shelf life(days)
Tommy	30	1	Y,T,M,EF,SL,SPD	High	High	Low	Low	Regular	>5
Bire	20	2	Y,EF,M,T,SL,SPD	High	High	Low	Low	Regular	2 to 5
Kent	19	3	Y,T,M,SPD,EF,SL	High	High	Low	Low	Regular	>5
Apple	17	4	Y,T,M,EF,SL,SPD	Moderate	Moderate	Low	Low	Regular	>5
Kate/Taka	11	5	Y,T,LPD,M,EF,SL	Low	Low	Moderate	High	Regular	2 to 5
taka									
Dodo	10	6	T,Y,SPD,EF,M	Low	Moderate	Moderate	High	Regular	>5
Ssuna	10	6	LPD,T,Y,EF,M	Moderate	Moderate	Moderate	High	Regular	2 to 5
Boribo	8	8	Y,SPD,EF,M,T	Moderate	Moderate	Low	Moderate	Irregular	2 to 5
Kagoogwa	5	9	LPD,Y,T,EF,M	Low	Low	High	High	Irregular	2 to 5
Zillate	4	10	Y,T,EF,M,SPD	Low	Low	Moderate	High	Irregular	2 to 5
Kayembe	4	10	T,M,LF,PY	Low	Low	High	High	Irregular	>5
sweet									
Lukazi	3	12	LPD,M,PY,LF,	Low	Low	High	High	Irregular	>5
Magada	1	13	PY,LF	Low	Low	High	High	Irregular	>5
Ssejjembe	1	13	PY,LF	Low	Low	High	High	Irregular	>5
Lunywa	1	13	PY,LF	Low	Low	High	High	Irregular	>5
Nyomo	1	13	PY,LF	Low	Low	High	High	Irregular	>5

Y= yield, T = Taste, M = Market, LPD = less susceptible to pests and diseases, PY = Poor yield, SPD = More susceptible to pests and diseases, EF = Early Fruiting, LF = Late Fruiting, SL = Shelf life. Reasons for rank are presented in decreasing order of preference

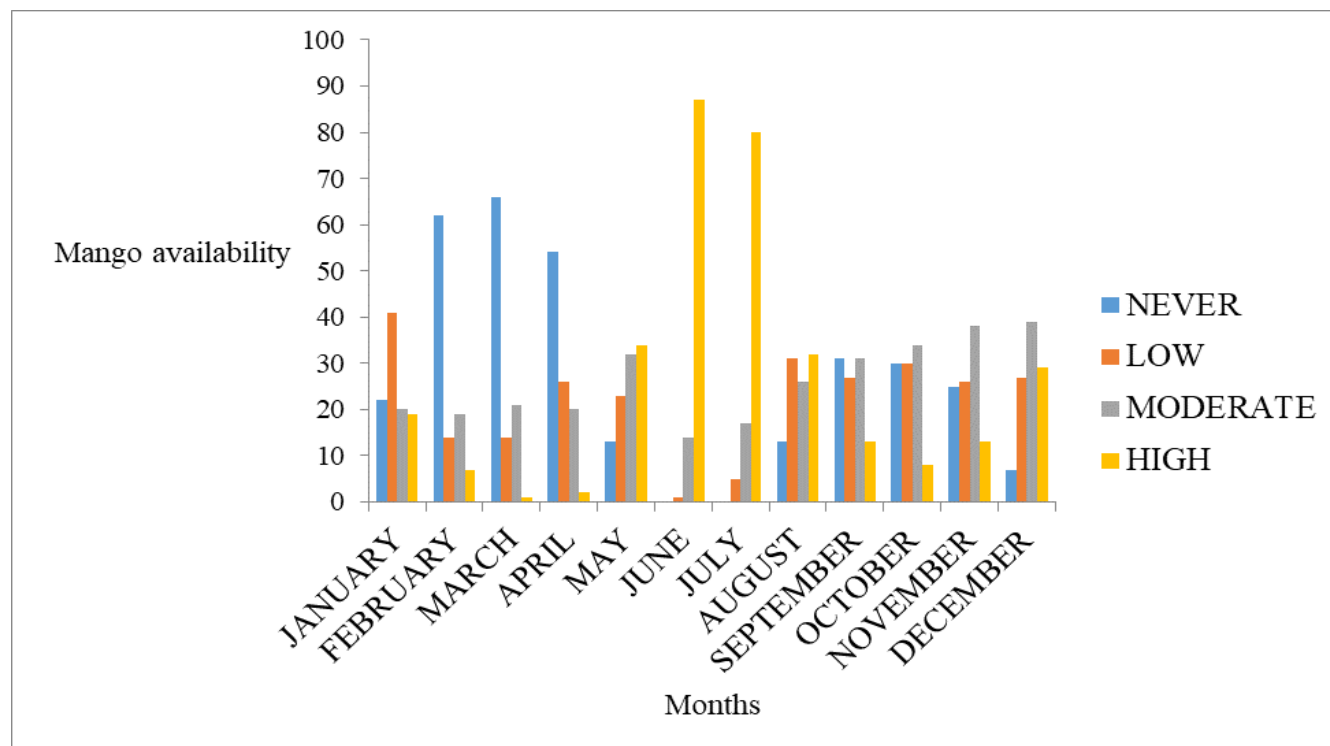


Figure 2. Seasonal availability of mangoes in the study area

Table 6. Production practices used

Practice	Frequency/year
spraying	3
Manuring	2
weeding	2
Pruning	2
Thinning	1

Table 7. Soil fertility practices

Practice	Percent response
intercropping	33.5
Organic inputs	23.2
Tillage integrated soil management practices	16.5
Crop rotation	9.8
Using fertilizers	9.1
Use of cover crops	7.9

Table 8. Harvesting practices in the study area

Harvesting stage	Percent response
Both	58.3
Partially ripe	20.8
Fully ripe	7.5
Harvesting method	
Hand picking	75.8
Using sticks	7.5
Harvesting time	
Any time of the day	70
Afternoon	8.3
Morning	5

Table 9. Post harvest practices in the study area

Practice	Percent response
Sorting	21.5
Grading	19
Washing and waxing	8.3
Post-harvest pest and disease control	7.8
Sap burn control	0.5
Use of ethylene	0.5
Removal of branches	0.5
Storage type	Percent response
Storage house	67.5
Shade under trees	15
Packaging	Percent response
Synthetic fiber sacks	11.7
Plastic box	4.2
Wooden box	39.2
Do not pack	26.6
Synthetic fiber sacks	11.7
Plastic box	4.2

Table 10. Production constraints, mitigation measures, and prospective recommendations for future enhancement.

Production constraint	Percent responses (%)	Control measures	Future suggestions
Pest and diseases	42.7	NO,SP,TP,BR,RP,	SP,TP
Low market	14.9	NO,TK,	VA,MS
Theft	9.1	NO,GF,WM,FN	FN
Drought	4.6	IR	SA
Flower and fruit abortion	4.6	NO,SP	SP,TP
High management costs	4.6	NO	LN
Ineffective sprayers	3.3	NO,CL,BRR	MP
Expensive trapping and spraying chemicals	3.3	NO	XS,LN
Perishability	2.5	NO,SP,TP,EH	VA,EH
No extension services	1.2	NS,NO	XS,
No processing machines	1.2	NO,	VA
Low yields	1.2	FA	FA
Animal pests	1.2	NO,FN	FN
Fake chemicals	1.2	NO	GC
Long maturation time	0.8	NO	BRD
Yield irregularities	0.8	NO	
Small land size	0.4	NO	SL

NO=Nothing, RP=Replacing Infected Trees, IR=Irrigation, GF=Giving freely, SP=Spraying, TK=Transport to Kampala, TP=Trapping, BR=Burying Infected Trees, CL=Climbing, BRR=Borrowing, WM=Watchman, FN=Fencing, EH=Early Harvesting, FA Fertilizer Application, VA=Value Addition, MS=Market Sourcing, SA=Soil Amendments, LN=Loans, XS=Extension Services, MP=Motorized Pumps, GC=Genuine Chemicals, BRD=Breeding, SL=Securing more Land

Incidence of Pests and Diseases in Mango Orchards and Associated Management Practices. The findings indicate that 66.7% of the respondents were able to identify the pests attacking their mango trees. The major pests reported in the area were fruit flies (97.5%), Caterpillars (1.3%) and Nematodes (1.3%). Fruit flies were associated with rotting of fruits (52%), sap oozing (44%), presence of the pest (17.3%), fruit drop (14.7%), dark/black discoloration (10.7%) and fruit maceration (8%). The other reported symptoms associated with fruit fly attack were exit holes on infested mangoes, and flower abortion. Plant parts attacked by fruit flies were mainly fruits (96.2%), flowers (12.8%), and leaves (1.3%). Fruit fly infestation severity score was computed at 16.4% while the incidence percentage was 39.5%.

Overall, 40.8% of the respondents were able to identify the diseases affecting their mango trees. The most prevalent diseases were Anthracnose (84.9%) and powdery mildew (15.1%). Symptoms associated with Anthracnose were dark spots (53.3%), sunken lesions (51.1%), leaf spots (6.7%), mangoes fruit necrosis (6.7%), folded leaves (4.4%) and fruit abortion (2.2%). Powdery mildew was associated with white powder on leaves (70%), and flower abortion (12.5%). Leaves were the most affected by anthracnose (57.9%), followed by fruits (22.4%), shoot tips (18.4%) and flowers (1.3%), respectively. Powdery mildew affected leaves (57.1%), fruits (21.4%), shoot tips (14.3%) and flowers (7.1%), respectively. Anthracnose disease severity score was computed at 39.3% while the disease incidence percentage was 89.2%.

Trapping (62%) and spraying (31%) were the most reported practices for pest management while, spraying (94.6%) was the most reported control measure for diseases (Table 11).

Table 11. Pest and disease management practices

Pest	Management practices
Fruit flies	Trapping, spraying, trapping and spraying, burying infected mangoes
Caterpillars	Spraying
Nematodes	Use of urine
Disease	Management practices
Anthracnose	Spraying, pruning
Powdery mildew	Spraying,

Mango yield loss to pests and diseases. The average percentage of mango yield lost to pests and disease attack was reported as 62.9% and the most susceptible stage was fruiting (32.5%) followed by flowering (22.5%). On average 51.7% of the respondents reported the use of fungicides/pesticides. Most of the people who applied fungicides/pesticides spent less than 50,000 shillings (22.5%). Farmers that reported to use both spraying and trapping as a pest management strategy lost a smaller percentage of their yield (30%) to pest attack as compared to those that were only spraying (66%) or trapping (50%).

Influence of soil nutrient availability on mango fruiting. Generally, the study area had a flat terrain topography (69.8%), savanna grassland vegetation (94.8%), a loamy soil texture (59.2%) and moderate drainage (90.6%). There was an association ($p < 0.05$) in the nutrient levels at 15 cm and 20 cm depths indicating that nutrient levels at 20 cm depended on the levels of nutrients at 15 cm across the thirteen sub-counties visited. Generally, the soils in the study area were adequate in nitrogen levels (52%), moderate in phosphorous (60%), sufficient in potassium (63.5%), very high in organic matter content (76%) and slightly alkaline with pH around 6 (57.3%).

Table 12. Nutrient levels across the different sub-counties in the two study districts

Sub-county	Nitrogen	Phosphorous	Potassium	Organic matter	pH
Kyangwali	Inadequate	Moderate	Sufficient	Very high	Alkaline (6)
Kiziranfumbi	Adequate	Moderate	Deficient	Very high	Alkaline (6)
Buhanika	Adequate	Moderate	Sufficient	Very high	Alkaline (6)
Buseruka	Adequate	Moderate	Sufficient	Very high	Alkaline (6)
Kitoba	Adequate	Moderate	Sufficient	Very high	Alkaline (6)
Kigolobya	Inadequate	Moderate	Sufficient	Very high	Alkaline (6)
Kyabigambire	Adequate	Moderate	Sufficient	Very high	Alkaline (6)
Buhimba	Adequate	Adequate	Sufficient	Very high	Alkaline (6)
Bujumbula	Adequate	Moderate	Sufficient	Very high	Alkaline (6)
Kahora	Adequate	Moderate	Deficient	Very high	Alkaline (6)
Busiisi	Adequate	Moderate	Sufficient	Very high	Alkaline (6)
Hoima municipal	Inadequate	Moderate	Sufficient	Very high	Acidic (4.5)
Kikuube Trading center	Inadequate	Adequate	Sufficient	Very high	Acidic (4.5)

Effect of nutrient availability on mango performance. Chi-square test indicated no association ($p > 0.05$) between soil nutrient levels and flower abortion, fruit drop and average yield per tree. However, nitrogen levels in the soil affected the average yield per tree with mango trees grown in nitrogen-deficient soils yielding less than 50 fruits per tree per season (Table 13).

Table 13. Effect of nutrient availability on mango tree fruit yield

Variable	Attribute	Nitrogen	Phosphorous	Potassium	Organic matter	pH
Average yield/tree	<50	inadequate	Moderate	sufficient	Very high	Alkaline(6)
	50-100	adequate	Moderate	sufficient	Very high	Alkaline(6)
	200-300	adequate	Moderate	sufficient	Very high	Alkaline(6)
	400-500	adequate	Moderate	sufficient	Very high	Alkaline(6)
	Above 500	adequate	Moderate	sufficient	Very high	Alkaline(6)

Existing mango value chain and its associated challenges. Generally, 66.7% of farmers grow mangoes for sale whereas 33.3% for mainly for home consumption. Farmers mostly sold mangoes to wholesalers (57.3%) at an average price of 500 shillings (US \$ 0.12) per mango (68.3%). The size of the fruit was the main price determinant (62%) and the unit of sale used was mostly boxes (64.7%). The main challenges encountered in selling mangoes were market, fruit perishability and mango transportation related factors. A summary of the existing value chain, associated challenges and corresponding solutions are presented in Table 14.

Table 14. Mango value chain and associated main challenges in the study area

Variable	Response	Percent response (%)
Sell mangoes	Yes	66.7
	No	33.3
Farmer clientele	Wholesaler	57
	Retailers	47.2
	Both	2.8
Average mango price (shs)	< 500	68.3
	500 – 1000	30.5
	>1000	12
Price determinant	Size	62
	Variety	20
	Market	16
Transportation	Motorcycle	33.9
	Bicycle	19.2
	Vehicle	21.1
	Human	25.6
Market ranking	Poor	57.8
	Good	42.2
Challenge	Percent response (%)	Existing Solutions
Low prices	24.5	Domestic consumption
Unreliable market	22.6	Domestic consumption, sourcing market outside region
Distant market	11.3	Hiring transport means, Sell on farm,
Perishability	9.4	Early harvesting, sell on farm
Rejection of partially ripen mangoes	9.4	Domestic consumption
Lack of storage facilities	8.8	House Storage
Expensive transport means	3.8	Sell to near market
Lack of transportation	3.1	Hiring Transport means
Unreliable brokers	1.6	Sell on farm
Lack of good packaging materials	1.3	Use of crates
Lack of market information	0.6	Obtaining market information
High taxes	0.6	Nothing
Rejection of some varieties	0.6	Domestic consumption, Matching market varietal preferences
Price fluctuations	0.6	Obtaining market information
Lack of City Council licenses to operate	0.6	Nothing

Farmers' choice of selling to retailers, wholesalers or processors was mainly associated ($p < 0.05$) with mango yield per tree per season, access to extension services and years in mango growing. However, factors such as household income, level of education, source of market information and belonging to farmer groups did not have significant association with the choice of marketing channel.

Farmers reported different marketing challenges as well as different average mango prices. A consideration of the average mango prices and buyers indicated that the type of buyers affected the average price of a mango. When cross-tabulated, the average price of a mango sold to wholesalers was higher (500 to 1000 shillings) than the average price of a mango sold to retailers (less than 500 shillings), as well as the monthly profit for selling to wholesalers was higher (1 to 2.9 million shillings) than to retailers (less than 1 million shillings).

Table 15. Association between choice of marketing channel and determinant factors

Variable	p-value
Household income	0.315
Education level	0.090
Yield per tree per season	0.000*
Farmer groups	0.303
Market information source	0.053
Extension services	0.049*
Years in mango growing	0.012*

* p-value significant at 0.05 level of significance

Most of the farmers (66.7%) did not belong to any farmer groups while 33.3% of the farmers belonged to at least one farmer group. A chi square test between farmers' belonging to groups and average yield per tree showed an association ($p=0.022$) where farmers belonging to groups had more yield (400-500 fruits/tree) in a season. The proposed interventions to enhance mango growing in the area are listed as in Table 16.

Table 16. Farmer proposed interventions and the responsible personnel

Interventions	(%) response	Responsible personnel
Value addition	19.1	Government, DAO
Provision of fertilizers	0.7	Government, NAADS
Subsidizing chemical prices	6.7	Government
Provision of Pheromone traps	6.4	Government, DAO, NAADS, Private sector
Extension services	17.4	Government, DAO
Forming farmer groups	5.7	Farmers
Providing quality seedlings	4.0	Government, NARO, NAADS
Providing valued varieties	1.7	Government
More effective Measures of fighting fruit flies	0.7	Government, DAO, Makerere University
Widening market base	12.4	Government, DAO, Mango farmers, Private sector
Improved spray pumps	7.7	Government, DAO, NAADS
Government sponsorships	1.0	Government
Providing genuine farm inputs	6.0	Government, Private sector
Increasing mango production base	1.0	Government, Farmers, District
Establishing model farms	1.7	District, Government
Providing market information	2.3	DAO, Government, NARO, District
More research in mango diseases	0.3	Makerere University
Follow-ups	2.3	DAO, NAADS
Technology advancement	1.0	Government
Loans	2.0	Government

Discussion

The study revealed variations in mango varieties' performance across the study areas, documenting commonly grown varieties, production constraints, and management practices. In this region, farmers commonly cultivate both local and improved mango varieties, often growing multiple types simultaneously. However, a significant proportion of respondents (61.7%) could only identify these varieties by their common names, typically based on characteristics such as shape, size, color, aroma, and taste. This reliance on common names for identification is a widespread phenomenon influenced by local culture, language, and community origins, observed globally (Bally, 2011). The diverse naming conventions in farmers' orchards pose challenges for accurate variety identification, as noted in studies conducted in Kenya (Sennhenn *et al.*, 2013). Some farmers attribute this difficulty to receiving planting materials from governmental and non-governmental organizations without proper briefing on varietal names and crop management. Despite these challenges, a minority of farmers (38.3%) could identify specific mango varieties, with "Tommy" emerging as the most preferred among them, consistent with previous studies highlighting Tommy Atkins as a popular mango cultivar due to its favorable traits such as high yield, extended shelf life, early fruiting, and strong market demand. The highest number of varieties at a single farm was 9, but the majority (27.5%) of farmers grew mostly three different varieties of mangoes. Therefore, diversity assessment characterization and evaluation of mango cultivars should be conducted to select the best-performing genotypes for the various agroecological zones of Uganda.

Similar to findings from previous reports, mango yield in the study area ranged from 200 to 300 fruits per tree, translating to approximately 400 to 600 fruits per year. Yield was significantly associated with various factors including tree spacing, access to extension services, and frequencies of weeding, pruning, and spraying. The availability of extension services was linked to better-performing orchards, underscoring the importance of such services in enhancing mango farmers' welfare and increasing profit margins. Higher frequencies of weeding, pruning, and spraying were also associated with improved mango yield, as reported in other studies. Shorter intervals between weeding and spraying may enhance orchard productivity by reducing nutrient competition, pests, and diseases.

Factors such as years of mango growing, age of the farmer, crop system, and manuring frequency did not significantly affect mango yield but showed positive correlations with it. This suggests that improvements in these factors could potentially increase mango yield, consistent with previous research highlighting the importance of tree age and irrigation time for mango production. Furthermore, seasonal availability of mangoes was noted, with farmers reporting scarcity in March and abundance in June and July. This pattern aligns with peak mango harvest seasons reported in other tropical regions, emphasizing the importance of strategic planning for mango production and marketing.

Mangoes are commonly grown as part of a mixed cropping system alongside bananas, beans, coffee, cassava, and maize, which offers several advantages such as additional income generation, resource conservation, and dietary diversification (Tiwari and Baghel, 2014). This practice has demonstrated increased profitability and performance in various countries (Raut and Jain, 2013). However, despite the benefits of mixed cropping,

there are challenges in orchard management. In the study area, mango trees were often planted irregularly, with varying spacing among farmers. A spacing of 8 meters by 8 meters was associated with higher yields, highlighting the importance of a regular planting pattern for maximizing mango productivity (Verheij, 2006). Furthermore, the majority of farmers neglected pruning, leading to trees with unsuitable architecture for pre- and post-harvest activities. Pruning is essential for fostering the growth of lateral branches, improving sunlight and air penetration, reducing pests and diseases, and enhancing yields and fruit quality (Griesbach, 2003; Hussen and Yimer, 2013). Irrigation frequency varied based on soil conditions, with proper irrigation being crucial during critical stages such as flowering, fruiting, and maturity for successful mango orchard development (Mirjat *et al.*, 2011). Weeding practices also varied, with most farmers weeding their orchards twice annually. However, increasing the frequency of weeding can significantly boost fruit crop yields by reducing competition for nutrients and water, improving the physical soil environment, and controlling some insect pests (Abouziena *et al.*, 2016; Ravishankar and Misra, 2016).

In terms of fertilization, the majority of mango growers in the study area did not apply fertilizers, though some utilized artificial and organic fertilizers at varying rates. Optimal fertilizer application has been shown to double mango crop yield, highlighting its importance in orchard management (Dong *et al.*, 2019). Additionally, pest and disease management practices varied, with some farmers spraying their fields with fungicides and pesticides. However, the frequency of spraying was generally low, contrasting with recommendations for more frequent applications to achieve full pest and disease control (Griesbach, 2003).

Harvesting practices varied among mango growers in the study area, with fruits typically harvested partially or fully ripened. It is crucial to harvest mangoes at the right maturity stage to prevent inferior quality and ensure a longer postharvest life (Sivakumar *et al.*, 2011; Ahmed and Ahmed, 2014). Hand picking was the predominant method of fruit harvesting due to its ability to minimize fruit bruising and damage, unlike other methods such as using sticks, which can cause mechanical damage (Hussen and Yimer, 2013). However, the absence of canopy management resulted in some trees being too tall, requiring harvesters to climb, which could compromise fruit quality (Neguse *et al.*, 2019). Harvesting predominantly occurs during the day, but it is recommended to harvest mangoes in the morning to minimize the risk of sap burn to the fruit skin (Amin *et al.*, 2008). Determining the proper maturity indices of Ugandan mangoes is essential to minimize losses.

Harvested mango fruits were mainly stored in storage houses rather than tree shades, hence lacking control facilities for regulating environmental variables such as relative humidity and temperature. Storing matured mango fruits in inappropriate conditions can lead to a short postharvest life, rapid softening, decreased fruit quality, and increased susceptibility to handling damage and pathogens (Emongor, 2015). Developing improved mango fruit storage methods is necessary to enhance fruit shelf life and maintain quality. Farmers reported a shelf life of above five days for mangoes, with factors such as microorganisms, improper harvesting, ripening conditions, and lack of appropriate storage facilities contributing to degradation (Baloch and Bibi, 2012). There were no standard packaging and transport systems used by farmers, with motorcycles, human labor, vehicles, and bicycles employed for transportation. Improper transportation and packaging of fruit contribute to high marketing costs, postharvest losses, and poor nutritional quality (Sivakumar *et al.*, 2011; Patel *et al.*, 2013).

Intercropping was the most popular method of ensuring soil fertility, followed by the application of artificial fertilizers and tillage integrated soil management practices. Intercropping, along with appropriate orchard management, can enhance soil fertility (Murmu *et al.*, 2018). Incorporating crop residues and fertilizers through conventional tillage practices improves soil aeration, reduces compaction, and decreases weed pressure (Tahat *et al.*, 2020). Crop rotation with legumes has been shown to increase nutrient content, particularly nitrogen, essential for mango tree growth and development (Rivera, 2009).

Intercropping emerged as the most popular method (33.5%) for ensuring soil fertility in the study area. Proper selection of intercrops and effective orchard management can enhance soil fertility (Murmu *et al.*, 2018). Similar to findings in Ethiopia (Neguse *et al.*, 2019), a minimal proportion (9.1%) of respondents applied artificial fertilizers to mango cultivation. However, implementing an appropriate fertilization system is crucial to prevent declines in yield and fruit quality, as well as to address nutrient imbalances that can lead to biannual bearing in mangoes (Shaaban and Mahmoud, 2012). Some mango farmers (16.5%) practiced tillage integrated soil management, while 9.8% utilized crop rotation with legumes (Table 7). Conventional tillage practices aerate the soil surface, reduce compaction, and minimize weed pressure by incorporating crop residues and fertilizers to enhance productivity (Tahat *et al.*, 2020). Crop rotation with legumes has been shown to increase nitrogen content, essential for mango growth and development (Rivera, 2009). Soil analysis indicated moderate levels of nitrogen (52%) and phosphorus (60%), sufficient levels of potassium (63.5%), high organic matter content (76%), and a pH around 6 (57.3%), suitable for mango cultivation (QDAF, 2015). However, the analysis did not quantify nutrient availability for mango trees. Future studies should assess nutrient requirements specific to mango trees in the area. Soil analysis also revealed that nitrogen levels significantly affected the average yield per tree, with mango trees in nitrogen-deficient soils bearing fewer than 50 fruits per tree (Table 13). Correcting soil nitrogen levels would enhance productivity.

The study identified several production constraints faced by mango growers in the study area, which align with challenges reported by mango farmers in Ethiopia (Neguse *et al.*, 2019) and other parts of the world (Fordjour, 2014; Micah and Inkoom, 2016; Kumar *et al.*, 2017). Pest and diseases emerged as the major constraints, affecting 42.7% of mango growers, consistent with earlier findings by Dibaba *et al.* (2019). Anthracnose and fruit flies were identified as the primary problems, with incidences of anthracnose disease and fruit fly infestation reported at 89.2% and 39.5%, respectively. Poor orchard management and lack of chemical inputs likely contribute to the prevalence of pests and diseases. Notably, Kikuube exhibited a significantly higher infestation of mango fruit flies compared to Hoima, possibly due to differences in orchard establishments, management practices, and mango varieties.

Various approaches were employed by mango growers to address pests and diseases, including the use of insecticides and fungicides, traps, burying infected plants, and replacing cut trees with healthy ones, consistent with previous reports (Acema *et al.*, 2016; Magloire *et al.*, 2018). However, several farmers did not implement any pest or disease management practices, highlighting the need for enhanced knowledge skills in monitoring, identifying, and implementing preventive measures to improve mango productivity.

Market restrictions and fruit theft were reported as the second most common constraints by mango growers. Previous studies have identified market challenges such as low prices and limited market accessibility as major barriers to mango production (Kumar *et al.*, 2017; Dibaba *et al.*, 2019; Neguse *et al.*, 2019). To address these challenges, farmers in the study area have sought markets outside the region, as suggested by Ddamulira *et al.* (2019), which can potentially allow them to sell fruits at premium prices.

Conclusion and Recommendations

Various agricultural initiatives in Uganda have been implemented to enhance mango cultivation. However, mango farmers continue to grapple with persistently low productivity levels. The study underscored the need for adoption of mixed cropping as a viable strategy for farmers to augment their income streams and diversify dietary options. Pest and disease infestations, notably by fruit flies, anthracnose, powdery mildew, caterpillars, and nematodes, emerged as critical impediments to mango production. Addressing these challenges warrants a comprehensive educational outreach to equip farmers with knowledge on mango pest and disease management. Future research endeavors should prioritize the development of effective control mechanisms targeting mango fruit flies and anthracnose. Furthermore, enhancing farmers' access to extension services and providing training in scientific orchard management practices are paramount for enhancing yield and fostering the industry growth. Given the limited scope of the study, conducted only in the districts of Hoima and Kikuube, undertaking broader nationwide assessments is indispensable. Such endeavors will facilitate the identification of mango cultivars, delineation of optimal production practices, and prevalent constraints, thereby fostering advancements in the mango cultivation sector across Uganda.

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