Vol. 20(6), pp. 458-473, June 2024
DOI: 10.5897/AJAR2024.16628
Article Number: 096AC7772276
ISSN: 1991-637X

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African Journal of Agricultural Research

Full Length Research Paper

Determinants of adoption of improved agronomic practices of (*Sesamum indicum* L.) production, challenges and opportunities in Lango sub region of Northern Uganda

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Received 31 January, 2024; Accepted 14 June, 2024.

Sesame is a key oilseed crop predominantly cultivated in Northern and Eastern regions of Uganda. Despite efforts to promote sesame production, adoption of improved agronomic practices remains low. This study assesses adoption intensity, determinants of improved agronomic practices, and opportunities for enhancing sesame production in Northern Uganda. The study employed multi-stage and purposive sampling to survey 123 sesame farmers in Lira and Kole districts. Results indicate a 50% adoption intensity for ten critical agronomic practices. Highly adopted practices included early planting (91.9%), weeding (88.6%), crop rotation (72.4%), timely harvesting (90.2%), and proper post-harvest handling (96.7%). Conversely, the least adopted practices were use of improved sesame varieties, recommended spacing, pesticides, fungicides, and fertilizers. A Tobit regression model revealed that young, unmarried farmers with lower education levels, but farming as their primary occupation and having 4-6 years of production experience, exhibited higher acceptance and adoption rates of improved agronomic practices. Overall, addressing challenges such as drought, declining soil fertility, pests and diseases, limited market access, and constraints in inputs and credit is crucial for increasing adoption of improved agronomic practices in sesame production.

Key words: Sesame, adoption, socio economic factors, improved technologies, extension services, agronomic practices.

INTRODUCTION

Sesame holds significant importance as an oilseed crop in Uganda, valued for its seeds in the local diet, extraction of edible oil, and incorporation into various foods (Sharma et al., 2021; Wacal et al., 2021). Sesame seeds are renowned for their high oil content, exceeding 55%, rich in essential unsaturated fatty acids. Specifically, oleic acid (35.9-42.3%) and linoleic acid (41.5-47.9%) constitute approximately 80% of total fatty acids, while saturated fatty acids such as palmitic acid (7.9-12%) and stearic acid (4.8-6.1%) make up less than 20% (Wei et al., 2015; Wacal et al., 2019). Additionally, sesame seeds are a source of essential minerals like potassium (K), phosphorus (P), magnesium (Mg), calcium (Ca), and sodium (Na), with a protein content ranging from 18.3% to 25.4% (Wacal et al., 2019; Abbas et al., 2022; Irshad et al., 2023). Thus, sesame seeds offer significant nutritional and health benefits for both humans and animals.

In Uganda, sesame cultivation is expanding, emerging as a major cash crop for edible oil production, particularly in the Northern, Eastern, and North Western regions (Munyua et al., 2013; Vorley et al., 2015). However, there has been stagnation in sesame production, evident from low production quantities recorded between 2008 and 2016 (FAO, 2023). Various factors, including agronomic practices and socio-economic conditions, contribute to the limitations faced by sesame production in Uganda. Challenges such as diseases and pests affecting sesame, declining soil fertility, and poor agronomic practices have been identified as significant barriers (Wacal et al., 2021). These challenges underscore the critical need for the development and adoption of improved agronomic practices.

Studies suggest that advancements in technology, such as breeding new crop varieties and enhancing agronomic practices like weed control, soil fertility management, crop rotation, optimal planting rates, and timely planting, can enhance agricultural outputs by increasing crop yields in Sub-Saharan Africa (Tadele et al., 2017; Varshney et al., 2019).

Adoption of agricultural technologies has direct effects that could be either observable or measurable. Such effects may include enhanced productivity, improved product quality and increased income (Michler et al., 2019; Thompson et al., 2020). However, several factors affect adoption of good agronomic practices among farmers. These factors include availability of land, family labour, pricing and profitability of enterprises, as well as peer influence, farmers' level of education and access to extension training programs (Weyessa et al., 2017; Karubang et al., 2019; Ochieng et al., 2019). For instance, several studies have been conducted on factors affecting adoption of good agronomic practices in Uganda especially in maize, sweet potatoes, beans and sorghum (Zawedde et al., 2014; Ekepu and Tirivanhu, 2016; Lance et al., 2016; Priegnitz et al., 2019; Teklewold et al., 2020). Moreover, it is reported that adoption of good agronomic practices such as intercropping, weeding, crop rotation and irrigation for maize encouraged through extension programs can significantly increase crop production, thus food security in Uganda (Pan et al., 2018). However, there are limited studies on factors affecting adoption of good agronomic practices of sesame production in Uganda.

Improved agronomic practices are a set of recommendations that improve the quality and safety of sesame products and involve activities of production, post-harvest handling such as processing, drying, storage, and transportation (Doko and Enwere, 2014). Several manuals on improved agronomic practices of sesame production can help farmers increase their sesame productivity if properly adopted (Bubbolini et al., 2016; Van Den Bos and Zee, 2016; Pan et al., 2018). These improved agronomic practices include proper variety selection, proper soil preparation, using recommended sowing dates or timely sowing and proper plant spacing, soil fertility management through fertilizers and organic amendments, weeding, pests and disease identification and control, selection of disease and pest free plants for harvesting and adherence to crop rotation practice (Terefe et al., 2012; Chipchase et al, 2019). Notably, land should be prepared to a fine tilth for elevated germination and crop establishment either on either flat beds or ridges/furrows, judicious fertilizer application, early planting, thinning at two weeks post-sowing, consistent weeding, integrated pest management to prevent pests such as webworms, early harvesting of mature sesame plants, threshing dry plants, and proper storage (Bubbolini et al., 2016).

However, for many smallholder farmers in developing countries, implementing these recommended practices remains a challenge due to various constraints. A study in Bangladesh to determine factors affecting adoption of good agronomic practices reported that availability of family labor, lack of improved seeds and availability of extension services significantly contribute to adoption of improved agronomic practices in sesame production (Miah et al., 2016). Similar factors are most likely to influence adoption of improved agronomic practices in Uganda.

Despite the potential of sesame production to enhance smallholder household incomes in Northern Uganda (Vorley et al., 2015), adoption of improved agronomic practices remains limited in farming communities. Moreover, there is a lack of studies examining the primary factors influencing the adoption of these

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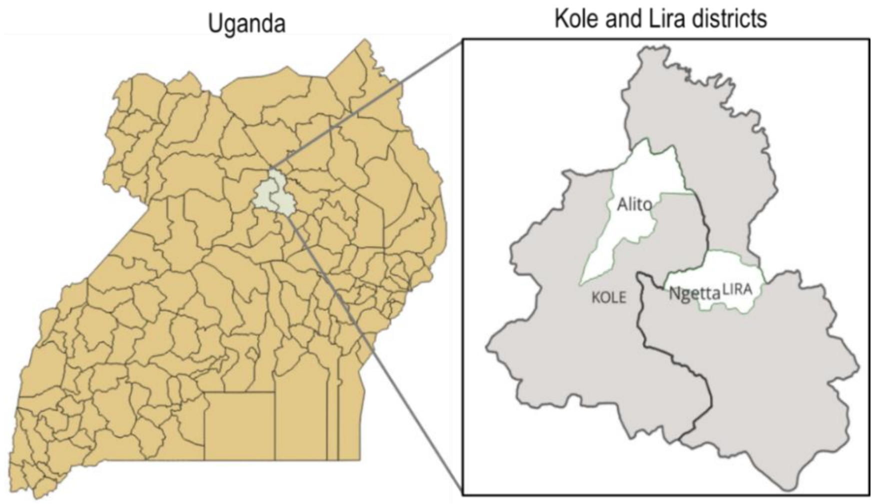

Figure 1. Map of the study area (generated by QGIS).

Table 1. Respondents used in this study.

Variable	Description	Frequency (n = 123)	Percentage
District	Kole	52	42.3
	Lira City	71	57.7
Sub county	Alito	63	51.2
	Ngetta	60	48.8

practices in Uganda. Therefore, this study aims to achieve three objectives: firstly, to establish the adoption intensity of improved agronomic practices; secondly, to identify key determinants influencing the adoption of these practices; and thirdly, to propose strategies for enhancing sesame seed productivity. The findings from this study will provide insights and recommendations to promote the adoption of improved agronomic practices, thereby boosting sesame seed production in the Northern region of Uganda.

METHODOLOGY

Description of study areas

The study was conducted in Lira City and Kole District, located in Northern Uganda. Lira City is situated approximately 337 km north of Kampala by road, with coordinates of 2°14'50.0"N latitude and 32°54'00.0"E longitude (Figure 1). The city has an estimated population of 99,059 (UBOS, 2014). The primary economic activity in Lira City revolves around subsistence agriculture, including the cultivation of maize, rice, groundnuts, millet, beans, sorghum, and oilseed crops such as sesame and sunflower.

Kole District is bordered by Lira District to the east, Apac District to the south, and Oyam District to the west and north. The district headquarters, Kole, is approximately 28 km northwest of Lira and about 290 km north of Kampala by road, with coordinates of approximately 02°24'N latitude and 32°48'E longitude. According to the 2014 census, Kole District had an estimated population of 239,327 (UBOS, 2014). Like Lira, agriculture is the predominant economic activity in Kole District, with a majority of smallholder farmers engaged in the cultivation of annual crops such as sesame and livestock rearing. These districts were selected for the study due to their significance as important sesame-producing regions in Uganda, reflecting their substantial agricultural activities and contributions to sesame production.

Sampling techniques

A multi-stage sampling procedure was employed for the selection of respondents for this study. Initially, two districts (Lira and Kole) were purposively chosen due to their significant sesame production. In the second stage, two sub-counties were purposively selected specifically because they are known for the second season sesame cultivation. The selected sub-counties were Ngetta in Lira district and Alito in Kole district (Table 1).

In this study, 42.3 and 57.7% of respondents were from Kole district and Lira districts, respectively (Table 2). The survey findings further revealed that of the total sampled farmers (n = 123), 51.2% were males and 48.8% females. While at the third stage, 123 farms (households) were purposively selected for cultivating sesame more than half acres from each sub county. This sample size was selected based on the formula of Krejcie and Morgan (1970) that assumed a 95% of confidence level and precision of 0.05 was

Table 2. Definition and description of selected variables use in the Tobit regression model.

Variable	Definition and description of variables
Dependent variable	
Adoption intensity (AI)	Continuous variable representing the intensity of adoption of improved sesame production technologies, with range of 0 to 1.0 (0 to 100%)
Independent variable	
Age	Dummy variable representing age of household head/farmer, 1 = 19-24 years, 2 = 25-35 years, 3 = 35-55 years, 4 = Above 55 years = 4
Marital status	Dummy variable representing marital status of household head/farmer, 1 = Single, 2 = Married, 3 = Widow, 4 = Widower 5 = Divorced/separated
Household size	Dummy variable representing number of members in a household, 1 = 1-3, 2 = 4-6 members, 3 = above 6 members
Education level	Dummy variable representing the highest level of education of the farmer, 1 = Primary =1, 2 = Secondary, 3 = Tertiary/university, 4 = None
Occupation	Dummy variable representing the main occupation of the farmer, 1 = civil servant, 2 = business man/woman , 3= Religious leader, 4 = Entirely farmer, 5 = Others
Farm size	Dummy variable representing farm size in acres, 1 = Less than 1 acre, 2 = 1-5 acres, 3 = 6-10 acres, 4 = More than 10 acres
Farming experience	Dummy variable representing year the farmer has taken in sesame production, 1 = 1-3 years , 2 = 4-6 years, 3 = above 6 years
Income from sesame	Dummy variable representing the income earned from last season's sesame harvested, 1 = Less than 200,000/=, 2 = 200,000-400,000/=, 3 = 400,000-600,000/=, 4 = above 600,000/=
Land tenure	Dummy variable representing land tenure system, 1 = Family inheritance,= Bought/owner, 3 = Rented/lease, 4 = Borrowed
Access to credit	Dummy variable representing whether farmer has access to credit or not = 1 if yes and 2 if no
Group membership	Dummy variable representing whether farmer a member to group or not = 1 if yes and 2 if no
Access to extension services	Dummy variable representing whether farmer has access to extension services or not = 1 if yes and 2 if no

adopted for this study (Equation 1). It was established that on average about 90 smallholder farm (households) produce sesame on not less than half an acre (2,000 m^2). For the two sub counties, the target population was 180 farmers (N = 180). It is from this target population where the sample size was calculated.

$$n = N / (1+N (e)^2) \quad (1)$$

where n = sample size, N = Target population, and e = level of precision of 0.05. Thus, the sample size for this study was 123 small holder sesame farmers who had grown sesame in the second season (July to December), were confirmed through field observations.

Data collection methods

This study used a combination of primary and observational data collection methods. 123 face-to-face interviews with small holder farmers were conducted during the field visit. The interviews followed a structured questionnaire administered by the researcher and trained enumerators. Additionally, field observations played a crucial role in corroborating the farmers' responses. The observations helped in capturing information not covered in the questionnaire and ensured a comprehensive data collection process.

Determination of adoption intensity

In this study, we used the adoption intensity of sesame production technologies which has been widely used by other authors (Ketema and Kebede, 2017; Kwawu et al., 2022; Midamba et al., 2024). Briefly, the improved sesame production technology is comprised of ten main components aimed at increasing yield. These included, the use of inorganic fertilizers, use of organic fertilizers, timely or early planting, use of row planting, weeding sesame plants twice or whenever necessary, practicing crop rotation of sesame with other crops, the use of pesticides or fungicides to control pests and diseases, harvesting sesame when 80% of capsules become yellow and finally, practicing proper drying, threshing and packaging sesame seeds in bags. Adoption scores were assigned to these components, totaling 100 points. To elaborate, if a sampled farmer adopted one component, the farmer was allocated 10 points, and where a farmer adopted all 10 components, the total points awarded would be 100 and considered a full adopter. Thus, the farmer's score increased with each additional adopted component. Then, the adoption index was calculated based on the formula reported by Midamba et al. (2024), in Equation 2:

$$\text{Adoption Index (AI)} = \frac{\text{Total number of technologies adopted by the sesame farmer}}{\text{Total number of technologies in the package}} \quad (2)$$

Data analysis

Descriptive and inferential statistics

To elucidate the socio-economic attributes of the sampled farmers, descriptive statistics like mean, percentage and frequencies were computed and regression model was generated by STATA statistical software version 14.0.

Econometric analysis

We used the Tobit regression model which is appropriate for dependent variable which is continuous and with a limit value. In this study, the dependent variable, "adoption intensity", is censored with a limiting value 0 and values ranging between 0 and 1. The model as described by Midamba et al. (2024) is defined in Equation 3:

$$AI^*_{ij} = X_{ij}\beta_i + U_i \quad (3)$$

Subject to:

$AI_{ij} = 0$ if $AI^*_{ij} < 0$
$AI_{ij} = AI^*_{ij}$ if $0 \le AI^*_{ij} \le 1$
$AI_{ij} = 1$ if $AI^*_{ij} > 1$

where AI = Adoption intensity; X_i is a vector of explanatory variables that can potentially influence adoption intensity.

β_i is a vector of parameter coefficients associated with the independent variables and U_i is the error term.

RESULTS AND DISCUSSION

Socio-demographic characteristics of the sesame farmers

The investigators asked about the socio-demographic characteristics of sesame farmers as summarized in Table 3. The findings reveal that most of the sesame farmers were males (51.2%), of 35 to 55 years of age (57.7%) and 25 to 35 years of age (33.3%), and majority were married (85.4%), with household size of 4 to 6 individuals (39.8%), and household heads had mostly attained primary education level (52%) and secondary education (32.5%) (Table 3). These results reveal that sesame is mainly produced by farmers in their productive age group because this age includes individuals that are raising a family which comes with economic stress thus, growing sesame could be seen as one of the key means of earning income to support the largely impoverished households.

Also, the age group (25-35 years) depicts that some youths are involved in sesame production. A similar finding has been reported in Nigeria which indicates that sesame is majorly cultivated by young farmers (Muhammad et al., 2022). The majority of the respondents (83.7%) were entirely engaged in farming as their major occupation, with sesame farming experience of four to six years. This implies majority of educated people in the region are not actively and directly involved in sesame production but engaged in other formal job settings.

Sesame production characteristics

The respondents were asked about the sesame production characteristics like source of land, amount of land allocated to sesame production, source of growing seed, varieties grown among others as presented in Table 4. Majority of farmers have reported that they use local (70.7%) varieties of sesame and much less of the improved Sesim I (4.1%) and Sesim II (0.8%) (Figure 2). Most of the local sesame seed is obtained from the local markets (61.8%) and s 29.3% of the farmers plant their own saved seeds. The results in Table 4 also show that majority of farmers were broad casting (94.3%) seed.

Table 4 indicates that most sesame farmers reported sesame yield per acre of less than 200 kg (87.0%) , with reported sesame yields of less than 100 kg (82.9%) of total yield per acre is sold, and also reported to earn income of less than USD 54 (87.8%) per season with only very few earned income of about USD 108. The yield reported by farmers in this study (less than 200 kg per acre of land), is far below the yield potential of sesame in other regions of the world, such as Europe, where yields reach an estimated 1,143 kg /ha (FAO, 2023). One of the reasons for low yields is the prevalent use of local varieties as reported by the 70.7% of the sesame farmers in the present study (Table 4). Interestingly, some sesame farmers are not aware of the varieties they grow even though there are improved varieties such as Sesim I and Sesim II with high yielding potential within their local communities, an indication of a very low level of awareness of the technologies available in their communities and/or completely disinterested in using any new innovations in sesame production. Local varieties are generally characterized by traits such as low yield, late maturity, susceptibility to pests and diseases and typically yield of mostly between 107 and 773 kg/ha

Table 3. Sociodemographic characteristics of the farmer.

Socio-demographic characteristics (n =123)	Frequency	Percentage
Gender		
Male	63	51.2
Female	60	48.8
Age (years)		
19-24 years	10	8.1
25-35 years	41	33.3
35-55 years	71	57.7
Above 55 years	1	0.8
Marital status		
Single	11	8.9
Married	105	85.4
Widow	5	4.1
Divorced/separated	2	1.6
Household size		
1-3 members	31	25.2
4-6 members	49	39.8
Above 6	43	35.0
Level of education		
Primary	64	52.0
Secondary	40	32.5
Tertiary/University	6	4.9
None	13	10.6
Occupation		
Civil servant	6	4.9
Business man/woman	11	8.9
Religious leader	3	2.4
Entirely farmer	103	83.7
Sesame farming experience		
1 to3 years	43	35.0
4 to 6 years	47	38.2
Above 6 years	33	26.8

Table 4. Sesame production characteristics.

Sesame production characteristics	Frequency	Percentage
Source of land for sesame production		
Family inheritance	103	83.7
Bought, owner	8	6.5
Rented/lease	7	5.7
Borrowed	5	4.1
Land allocated to sesame production (acre)		
Less than 1	45	36.6

Table 4. Contd.

2	73	59.3
3	1	0.8
More than 3	4	3.3
Awareness of sesame varieties		
Sesim II	5	4.1
Sesim III	1	0.8
Local variety	87	70.7
Don’t know	30	24.4
Source of planting seed		
Local market	76	61.8
Neighbor	6	4.9
Seed companies	5	4.1
Farmer saved seed	36	29.3
Planting methods		
Broadcasting	116	94.3
Row planting	3	2.4
Dibbling	4	3.3
Yield per acre (kg)		
Less than 200	107	87.0
200-300	11	8.9
300-500	5	4.1
Quantity of seed sold (kg)		
Less than 100	102	82.9
100 to300	12	9.8
300 to 400	8	6.5
Above 500	1	0.8
Income earned from sesame (US $)		
Less than 54	108	87.8
54 to 108	14	11.4
108 to 162	1	0.8
Above 162	0	0.0

1 USD = UGX 3700, UGX=Ugandan shillings.

in Uganda (Wacal et al., 2021). Thus, in this study, it is evident that sesame farmers are experiencing low production and productivity and earn low incomes from the use of the traditional low-yielding varieties.

Sesame farmers access to financial credit, belonging to farmer groups, and receiving agricultural extension training on sesame production is summarized in Table 5. The results also reveal that majority of sesame farmers interviewed do not have access to credit (95.1%), neither belong to farming groups (100%) nor received extension trainings on sesame production (95.9%) (Table 5).

Characterizing improved agronomic practices adopted by the farmers

The various sesame production technologies adopted by the farmers is shown in Figure 3. The descriptive analysis revealed that the most practiced sesame production technologies among farmers were early planting (91.9%), weeding twice (88.6%), crop rotation (72.4%), harvesting when 80% of the capsules turned yellow (90.2%) and drying, threshing and packaging in bags (96.7%) (Figure 3). Most farmers use the traditional windrow drying

Figure 2. Sesim II (purple variety) and a local variety (left) broadcasted on farmers' fields visited. Author: Cosmas Wacal.

Table 5. Farmers' access to sesame production services.

Access to sesame production services	Yes		No	
	Frequency	Percentage	Frequency	Percentage
Access to credit	6	4.9	117	95.1
Belonging to groups	0	0.0	123	100.0
Received extension training	5	4.1	118	95.9

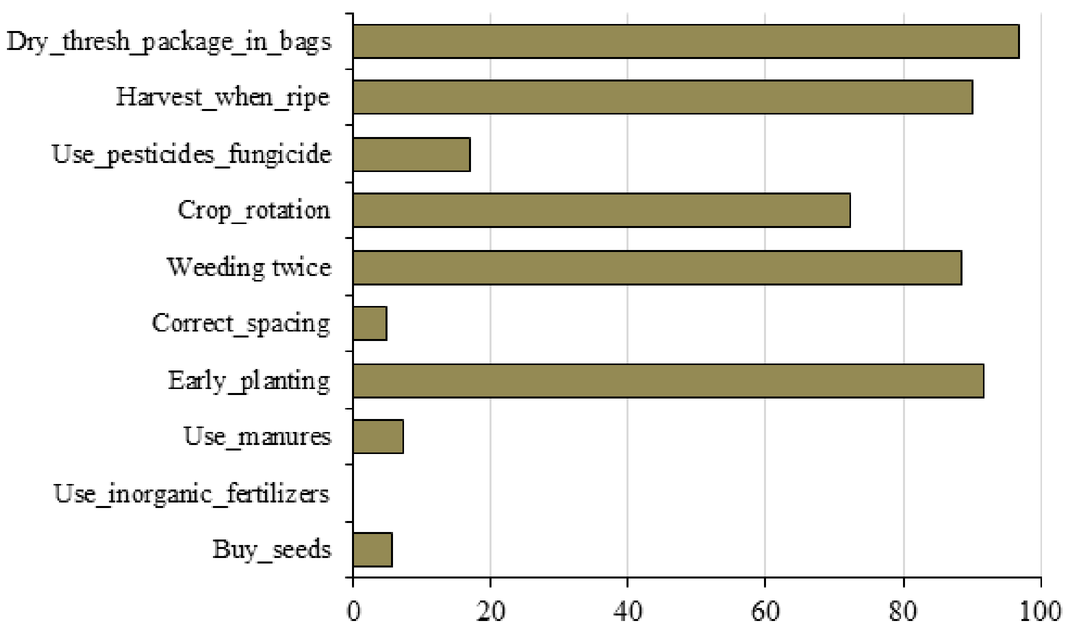

Figure 3. Use of sesame production technologies practiced by the farmers.

Figure 4. Harvested sesame plants harvested and dried using the traditional rack method.

method (Figure 4). These results imply that sesame farmer have adequate knowledge on importance of timely weeding, harvesting and key post-harvest handling technologies of sesame to avoid yield losses. This may be explained by the fact that sesame is a traditional crop in the Lango region and knowledge on its management has been passed down from previous generations to to different farming regions and it is obvious that all farmers are aware when to weed, harvest and dry sesame. It is known that traditional agricultural knowledge plays a crucial role in the adoption of improved agronomic practices such as timely weeding, pests and disease control as well as traditional post-harvest management (Sharma et al., 2023). Such traditional knowledge enables farmers to make informed decisions about crop husbandry and farm-related activities, leading to improved productivity and sustainability (Sun et al., 2022). Therefore, increasing farmers' access to and understanding of traditional agricultural knowledge is essential for promoting the adoption of sustainable crop production technologies.

On the other hand, results showed that the least adopted agronomic practice include the use of improved sesame varieties, recommended spacing, and crop protection chemicals i.e. pesticides and fungicides for pests and disease control. As expected, there were no farmers that use inorganic fertilizers (0%) during sesame production. These results imply sesame farmers in this region lack of knowledge on modern agronomic practices of sesame production related to crop protection and soil fertility management among the sesame farming. Indeed, research shows that sesame pests, diseases, limited use of improved varieties and declining soil fertility are major challenges hampering sesame yield (Wacal et al., 2021). Creating awareness on pests and diseases and soil fertility management is crucial for rural farmers. Research has shown that awareness campaigns and interventions on soil fertility management, pests and disease control and use of improved varieties are essential for increasing crop productivity on smallholder farming systems (Al Basir et al., 2023; Ngoya et al., 2023). Information and communication technology (ICT) tools, such as mobile phones, can play a significant role in raising awareness among farmers and enhancing their capacity for data-driven decision-making. Farmer knowledge and management practices, integrated with soil type and quality, are essential for managing soil-borne pests and diseases in smallholder farming systems. Overall, creating awareness among rural farmers on the use of fertilizers, pesticides, fungicides and recommended spacing is crucial for sustainable sesame production.

Determinants of adoption of improved sesame production technologies

The results show that the mean adoption intensity is at 50% which is average (Table 6). The result also shows that, 60% of the sesame farmers scored up to a 50% adoption intensity. This was followed by 24% of the farmers who scored 40% adoption intensity whereas 2.4% scored 0.3% the lowest adoption intensity. Similarly, at 80% adoption intensity, there were very few sesame farmers (4.1%). The minimum and maximum adoption intensities are 0.3 and 0.8, respectively. The Variance Inflation Factor (VIF) was to assess the presence of multicollinearity in the regression model (Table 7). The results showed that all the VIF had values less than 10, indicating no severe multicollinearity among the selected variables in the Tobit regression model. In

Table 6. The adoption intensity of improved sesame production technologies.

Adoption intensity (Intensity range (0–1))	Frequency (n)	Percent
>0.1	0	0
0.3	3	2.4
0.4	29	23.6
0.5	74	60.2
0.6	9	7.3
0.7	3	2.4
0.8	5	4.1
>0.9	0	0
Total	123	100
Mean adoption intensity	0.496	
Min.	0.3	
Max.	0.8	

Table 7. The VIF and other pre-estimation test results before performing the Tobit regression analysis.

Variable	VIF	1/VIF
Gender	1.13	0.887898
Age	1.47	0.678037
Marital status	1.4	0.715753
Education level	1.19	0.842408
Occupation	1.28	0.781148
Farm size	1.34	0.746339
Farming experience	1.63	0.613717
Income from sesame	2.25	0.44427
Land tenure	1.27	0.784787
Access to credit	1.37	0.730703
Group membership	1.95	0.513265
Access to extension	1.3	0.771063
Mean VIF	1.46	

Table 8. Association between socio-economic factors and adoption of improved agronomic production.

Adoption intensity	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Gender	0.020	0.015	1.410	0.163	-0.008	0.049
Age (years)						
25-35	0.059	0.030	1.990	0.049*	0.000	0.118
35-55	0.040	0.033	1.210	0.230	-0.026	0.105
Above 55	-0.041	0.050	-0.820	0.413	-0.140	0.058
Marital status						
Married	-0.090	0.030	-3.040	0.003**	-0.149	-0.031
Widow	-0.237	0.049	-4.880	0.000***	-0.333	-0.140
Divorced/Separated	-0.284	0.066	-4.310	0.000***	-0.416	-0.153

Table 8. Contd.

Household size						
4-6 members	0.004	0.020	0.220	0.824	-0.035	0.043
Above 6 members	0.014	0.023	0.590	0.554	-0.032	0.059
Education level						
Secondary	0.015	0.016	0.920	0.359	-0.017	0.048
Tertiary	-0.041	0.039	-1.050	0.295	-0.119	0.036
None	0.086	0.027	3.210	0.002**	0.033	0.139
Occupation						
Business man/woman	0.018	0.056	0.330	0.744	-0.093	0.129
Religious leader	-0.115	0.063	-1.820	0.072	-0.241	0.010
Entirely farmer	-0.119	0.047	-2.550	0.013*	-0.212	-0.026
Others	-0.035	0.070	-0.500	0.621	-0.174	0.104
Farm size (acres)						
1-5	-0.011	0.020	-0.520	0.607	-0.051	0.030
6-10	-0.039	0.034	-1.150	0.254	-0.106	0.028
Farming experience (years)						
4-6	0.038	0.017	2.210	0.029*	0.004	0.071
Above 6	0.024	0.022	1.120	0.267	-0.019	0.068
Income from sesame (USD)						
54-108	0.033	0.025	1.310	0.192	-0.017	0.083
108-162	-0.220	0.101	-2.180	0.032*	-0.419	-0.020
Above 162	-0.186	0.095	-1.960	0.053*	-0.374	0.002
Land tenure						
Bought,owner	-0.008	0.028	-0.270	0.788	-0.064	0.049
Rented/lease	0.004	0.030	0.130	0.900	-0.055	0.063
Borrowed	0.002	0.035	0.070	0.947	-0.066	0.071
Access to credit	0.026	0.025	1.040	0.303	-0.023	0.075
Group membership	-0.122	0.062	-1.960	0.053	-0.246	0.002
Access to extension	-0.073	0.035	-2.100	0.039*	-0.142	-0.004
Constant	0.777	0.095	8.210	0.000***	0.589	0.965
/sigma	0.067	0.004			0.058	0.076

*, **Significant at 0.05 and 0.01 level of probability.

addition, the corresponding tolerance values (1/VIF) were all greater than 0.1, with the highest VIF value of 2.25 corresponding to a tolerance value of 0.444. The results of VIF suggest that there was a relatively low level of multicollinearity among the selected variables for Tobit regression model. Thus they can be considered for running the model.

The Tobit regression model results of determinants of adoption of improved sesame technologies are presented on Table 8. The age of famers especially those between 25 and 35 years of age had a positive and significant (P <0.05) effect on the adoption of improved sesame production technologies. This implies that young farmers have higher acceptance and adoption of improved agronomic practices of sesame production more easily than older farmers. This could be attributed to the fact that they have better levels of education, wider social networks, and higher responsiveness to the use of agronomic practices and information in improving agricultural production performance (Novisma et al., 2023). Since young or youthful sesame farmers are more open to embracing improved agronomic practices, it is therefore important to engage more youths to adopt sesame farming and increase production in the Northern region of Uganda.

Furthermore, the Tobit regression model showed that marital status (married, widow and divorced/separated) had a negative and significant ($P < 0.01$ for married, 0.001 for widow and divorced) effect on the adoption of improved sesame production technologies which implies married people were not that able to manage their sesame fields properly. Perhaps they were engaged in other activities to sustain the families. Married farmers may not have the urge to practice adopt the improved agronomic practices agriculture due to several factors. One factor is the traditional gender roles and division of labor in rural areas, where the husband is seen as the head of the farm and responsible for decision-making, while the wife is expected to take care of household tasks and routine agricultural activities (Vercillo et al., 2020. This gendered division of labor can limit the wife's recognition and independent status as a farmer, leading to a weaker occupational identity (Kaberis and Koutsouris, 2013). Furthermore, the burden of housework especially on women who engaged in agriculture is a contributing factor for lack of adoption of improved agronomic practices of practice among married farmers (Ayoade, 2013).

Educational attainment had a significant positive effect ($P < 0.01$) on the adoption of improved sesame production technologies. Surprisingly, sesame farmers with no formal education tended to adopt agricultural technologies better than those who had attended secondary and tertiary institutions. Moreover, occupation, particularly being solely a farmer, had a significant negative effect ($P < 0.01$) on the adoption of improved sesame production technologies, indicating that farmers relying entirely on agriculture showed lower adoption rates. Ideally, one would expect that farmers with higher levels of education, up to secondary schooling, would exhibit a higher adoption intensity (above 50%). However, many of these educated farmers were not fully engaged in sesame farming as their primary occupation. As highlighted by Muhammad et al. (2022), formal education is typically seen as crucial for adopting sesame technologies, but our study's findings suggest otherwise. This discrepancy may be due to educated farmers being more likely to seek formal employment, such as civil service positions, which limits their time for sesame production.

These findings indicate that sesame production is predominantly carried out by farmers with minimal education and who are not employed in the formal sector. One contributing factor could be the lower social status associated with agriculture, which discourages educated individuals from pursuing careers in this field (Jjuuko, 2022). Evidence reveals that youth engagement in agriculture is declining, and factors such as enhancing soil productivity, access to technical knowledge and information, and access to land for production are significant barriers to youth engagement in agricultural enterprises (Loga et al., 2022). In addition, Uganda's economy heavily relies on agriculture, but low agricultural productivity, lack of value addition, and limited infrastructure and markets contribute to the perception that agriculture is less attractive to educated youths (Epeju, 2020). Therefore, most educated youths including mature farmer category are not attracted to agriculture at production level but instead involved in the formal job sectors and thus, efforts are a needed to increase participation of educated people in agriculture including sesame production.

Experience in sesame farming, particularly having 4-6 years of experience, had a significant positive effect ($P < 0.05$) on the adoption of improved sesame production technologies. This suggests that farmers with relatively less experience are capable of adopting these technologies, especially traditional practices like weeding, harvesting, and post-harvest handling. It indicates that sesame production technologies may not be overly complex for farmers to implement, though there remains a need for awareness and training on modern sesame production practices and technologies. Conversely, income derived from sesame, ranging between 108 and 162 USD, had a significant negative effect ($P < 0.05$) on the adoption of improved sesame production technologies. This implies that income generated from sesame production does not drive the adoption of advanced technologies. It also suggests that sesame production in the study area is primarily oriented towards subsistence rather than commercial agriculture, with a focus on meeting household food needs and selling any surplus. Unlike subsistence agriculture, which aims to meet immediate household needs, commercial agriculture is profit-oriented. Although Uganda's agricultural sector is predominantly subsistence-oriented, efforts are underway to promote commercial agriculture (Nabwire et al., 2015). Therefore, there is a critical need to raise awareness among farmers in the region about the market demand for sesame. This could encourage them to view sesame as a viable commercial cash crop, thereby fostering greater adoption of improved agronomic practices for sesame production.

Finally, access to extension had a negative and significant, ($P < 0.05$) effect on the adoption of improved sesame production technologies indicating it is not the access of extension services that drive adoption of improved sesame production technologies. This is contrary to the fact that access to agricultural extension training play a crucial role in adoption of improved agricultural technologies (Wang et al., 2017; Yitayew et al., 2021). This is because extension services provide farmers with improved access to information and skills, leading to greater innovation and productivity on family farms (Jara-Rojas et al., 2020). In this study, the lack of adoption of full good agronomic practices of sesame despite the access to agricultural extension training could indicate that sesame production technologies are not

Table 9. Constraints to sesame production as perceived by farmers.

Challenge	Not Applicable		Very serious		Serious		Less serious	
	Frequency	%	Frequency	(%)	Frequency	(%)	Frequency	(%)
Lack of access to improved seeds	0	0	54	43.9	65	52.8	4	3.3
Lack of access to inorganic fertilizers	0	0	47	38.2	71	57.7	5	4.1
Lack of access to credit	2	1.6	49	39.8	67	54.5	5	4.1
Limited extension training	0	0	101	82.1	19	15.4	3	2.4
Limited farm labour	0	0	22	17.9	37	30.1	64	52.0
High pests and diseases	0	0	57	46.3	47	38.2	19	15.4
Poor soil fertility	0	0	58	47.2	56	45.5	9	7.3
Drought/unpredictable rainfall	0	0	93	75.6	24	19.5	6	4.9
Limited markets	1	0.8	56	45.5	23	18.7	43	35.0
Unstable prices for sesame	2	1.6	65	52.8	12	9.8	44	35.8

included on the training programs and perhaps extension agents and partners have prioritized other crops rather than sesame. It is evident in Sub Saharan Africa that the adoption of yield-enhancing technologies by smallholder farmers remains low, but improved extension services can positively influence farmers' decisions to try new varieties and technologies. A research by Kafando (2023) on the impacts and the adoption of sesame seeds on productivity of sesame farms in Burkina Faso and found that adoption of improved sesame technologies could be promoted through enhancing agricultural extension trainings. Thus, there is need to improve on extension services to include sesame production technologies in Northern Uganda and the Sub Saharan Africa at large to increase its productivity.

Perceived challenges affecting production of sesame and strategies towards its enhancement

Among the challenges highlighted by the sesame farmers, those that were ranked to be very serious by several farmers include limited extension training (82.1%), followed by drought/unpredictable rainfall (75.6%), unstable prices for sesame (52.8%), poor soil fertility (47.2%), high pests and diseases incidences (46.3%), limited markets for sesame seeds (45.5%), lack of access to improved seeds (43.9%), lack of access to credit (39.8%), lack of access to inorganic fertilizers (38.2%) and limited farm labour (17.9%) (Table 9). Socio-economic factors such as lack of access to improved seeds (52.8%) and lack of access to credit (54.5%) were also reported as important challenges faced by the sesame farmers while limited farm labour was considered a less serious challenge by a section of sesame farmers (52.0%). Indeed these are the key constraints affecting sesame producers in Uganda as reported by Wacal et al. (2021). The lack of access to improved seeds implies the newly developed sesame varieties have not been well promoted among the farming communities in the Lango sub regions and lack of access to credit signifies the need to provide farmers with cheap loans through cooperatives and agricultural financing agencies. Fadeyi et al. (2022) in their systematic review found that credit (finance), education and extension access are the leading factors that influence adoption of technologies among smallholder farmers. Furthermore, Lubwama (2015) also observed that provision and improving access to credit facilities is one way of promoting adoption of agricultural technologies. Usually farmers will require credit or finances to purchase improved seeds, fertilizers, pesticides, fungicides and paying off labor on the farm.

Furthermore, majority of farmers reported that sesame production is hampered by pests and diseases and poor soil fertility. This is true because sesame is prone to diseases such as sesame phyllody which is deformation of flower parts of sesame that makes appearance like leaves and reduces seed yield, and diseases of such as *Fusarium wilt* and leaf spots that cause significant yield losses in sesame production (Ngamba et al., 2020; Kafando, 2023). On the other hand, major pests include *Antigastra catalaunalis* and *Asphondylia Sesami* were noted as the major pests contributing to 62 and 98.8% of pest occurrences respectively in addition to web-worm or leaf roller that are responsible for estimated 90% of yield losses due to pests in Uganda (Egonyu et al., 2009). Furthermore research indicate that soil fertility decline due to continuous cropping has significantly affected sesame yields (Wacal et al., 2021). The loss in soil fertility affecting sesame yields could be compensated by adding inorganic and organic fertilizers such as manure. Unfortunately very few sesame farmers responded that they use the manures in sesame production and therefore there is need to create awareness on the use of such soil fertility enhancement practices among sesame farmers. When asked about what can be done to promote sesame production, majority (of sesame farmers (49.6%) requested for provision of free inputs such as improved seeds, pesticides and fungicides, followed by improving

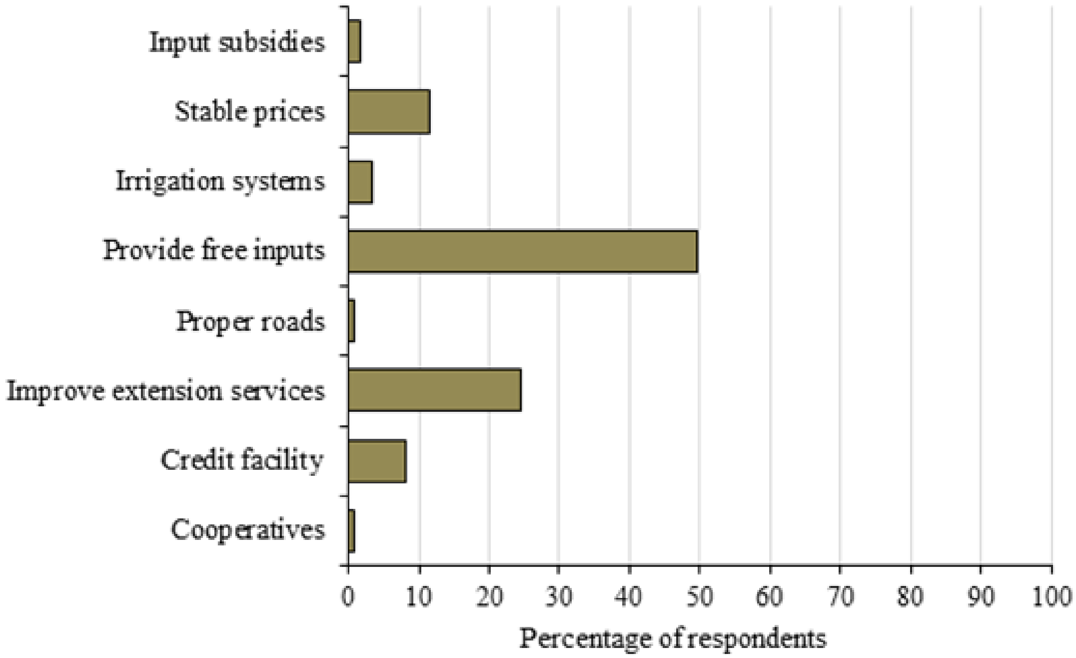

Figure 5. Opportunities to improve sesame production in the Lango sub region.

extension service delivery (24.4%), stabilizing sesame seed prices (11.4%), provision of credit facility (8.1%) and irrigation facility (3.3%) (Figure 5).

There is need to raise awareness on the use and importance of improved high yielding sesame varieties in the Lango sub region. Following the responses on what interventions should be put in place, farmers expected provision of inputs such as improved seeds, pesticides and fungicides, fertilizers and improving extension service delivery, stabilizing sesame seed prices provision of credit facility and irrigation facility. Umar et al. (2011) found that poor access to credit facility, high cost of inorganic fertilizer, poor extension service, and low market price for sesame seeds were the key constraints to sesame production in Nigeria meaning that these needed to be addressed to promote production. Furthermore, since sesame farmers reported that drought/unpredictable rainfall is also a challenge, it is important to provide trainings and access to low cost irrigation technologies to overcome periods of long dry spell. Usually sesame in Uganda is produced under rain fed agriculture which is prone to drought due to climate change. Sesame like any other crop responds positively to irrigation through increased yields. In a study to determine the effect of irrigation regimes on yield, yield attributes of two sesame cultivars (Giza 32 and Toushki 3) in Egypt, it was found that irrigation every 7 or 9 days resulted in the highest sesame yield, and medium irrigation regime is recommended (Abd El-Lattief, 2015). Thus, it is important to create environments for promotion of irrigation technologies and also adoption of drought tolerant sesame varieties.

Conclusion

This study determined the level and determinants of adoption of improved agronomic practices of sesame as well as production, challenges and opportunities in Lango sub region of Northern Uganda. The findings revealed that the mean adoption intensity was 50% of the improved agronomic practices. Highly adopted practices included early planting, timely weeding, crop rotation, timely harvesting and proper post-harvest handling whereas the least adopted were the use of improved sesame varieties, recommended spacing, pesticides and fungicides, organic and inorganic fertilizer use. This implies that several interventions are needed to elevate the adoption to full level. The findings also show that young, highly experienced and without any off farm employments, having access to extension services, were the key determinants of adoption provided sesame prices were high and stable, while those highly educated and employed by the formal job sectors such as civil servants as their major occupations had low the rate of adoption. Overall, this study suggested that in promoting adoption of improved agronomic practices of sesame, it is important to consider the youthful farmers, as well as those lowly educated but experienced farmers and these should have access to frequent extension services. Moreover, it is important to relieve various challenges such as drought, declining soil fertility, pests and diseases, and limited access to inputs and credit binding farmers from adoption improved agronomic practices in sesame production. However, the decision to adopt improved agronomic practices among farmers may vary across different regions as the explanatory variables change. Further studies should include a wide range of explanatory variables while expanding the geographical scope including sample size across other regions to better understand determinants of adoption of agronomic practices in Uganda.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors appreciate Mr. Aporo Simon for leading the data collection team. They also appreciate the voluntary participation of every respondent who took part in this study.

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