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Economic analysis of sesame (*Sesamum indicum* L.) production in Northern Benin

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Introduction: Sesame is an important cash crop that can be grown with limited resources. In recent decades it has drawn interests of many researchers and developers. This study analyzed the economics of Sesame (*Sesamum indicum* L.) produced in northern region of the Republic of Benin.

Methods: Structured questionnaire was used to gather primary data from 120 farmers who made up the sample size and were chosen using a multistage sampling technique. Data were analyzed using descriptive statistics, profitability analytical tools, multiple regression analysis and Likert scale rating technique. Profitability analytical tools were used to assess the economic performance of the sesame production; a multiple regression model was used to analyze factors that determine the output of the production in the study area; a 5-point Likert scale rating technique was utilized to rank the production's challenges according to farmers' observations.

Results: The findings revealed that sesame is mainly produced in sole cropping system and in rotation with other crops. The net farm income analysis showed that sesame farming was a profitable venture in the study area. The study also showed that factors like age, household size, crop rotation, and capital input influence the revenue of sesame production. While age, household size and capital input have a beneficial and significant influence on the farms' net revenue from sesame produce, crop rotation has a negative effect on it. Amongst the various constraints identified, the most significant ones are access to labor and land, uneven ripening, lack of storage facilities and access to improved seed.

Discussion: Based on these results, authorities in agricultural sector should develop and promote this value chain at the national level as it will greatly boost the country's economy.

KEYWORDS

food supply, determinants of output, sole cropping system, profitability, constraint

Introduction

The economy of Benin depends heavily on the agricultural sector, which has great potential for creating jobs, ensuring food security and reducing poverty (Dossa and Miassi, 2018). The oldest crops grown for food are cereals, with maize, sorghum, and sesame being the most important (Suraj et al., 2021). Sesame (*Sesamum indicum* L.) is an ancient and important oleaginous crop that is grown mainly in the tropical and subtropical regions of Asia, Africa, and South America. It belongs to the Pedaliaceae Family, the genus of Sesameae and adapted to hot areas (Weiss, 2000; Stevens, 2012). Sesame is a significant crop farmed in almost all nations in West and Central Africa, with Nigeria and Burkina Faso being the top producers. It serves as an alternative cash crop that generates income for smallholders, especially women (UN, 2016; Dossa et al., 2017). Sesame seed demand is rising quickly all over the world, and West African sesame seed is particularly valued because it is produced largely without pesticides. Sesame has grown to be a significant agricultural export good, affecting millions of farm households (Dossa et al., 2016). Sesame cultivation has recently increased due to its drought resistance and easy growing circumstances, but most crucially due to farmers' need to diversify their sources of income (Dossa et al., 2017; Sadiq et al., 2020). The need is brought on by climate change, which has worsened the agrarian environment, reduced production of food crops (millet, sorghum and maize), and decreased production of the main cash crop (peanut) (Sene et al., 2018).

In addition to its economic, pharmaceutical and food interests, sesame farming has agronomic advantages in the crop rotation system (Lobell et al., 2008; Verma et al., 2016). In West Africa, more agricultural areas are expected to get drier and hotter as predicted by climate change experts (Boro et al., 2014). This leads to the problem of food insecurity because agriculture in rural areas in Africa is highly dependent on climatic conditions. Given the critical importance of agriculture for rural livelihoods in the West African Sahel region, it is crucial to prioritize and encourage the production of crops that can survive and give high yields sustainably under adverse environment precipitated by climate change (Langham, 2007). In this context, sesame (*Sesamum indicum* L.) is undoubtedly one of the resilient crops best suited to the West African Sahel's arid climate. It is cultivated in marginal lands and underprivileged areas during frequent severe droughts (Ayana, 2015). Unfortunately, little is known about this crop in Africa from empirical research (Dossa et al., 2017). It is a crop that is attracting more and more attention from developers in the agricultural sector and is, therefore, a crop of interest (Sene et al., 2018). However, compared to other crops, the sesame production is still very low (Girmay, 2018). In addition, research on sesame has been limited worldwide, which may have resulted in its being produced under traditional management practices (Girmay, 2018).

Few research programs are focused on the crop resulting in very sparse scientific data about the production status in West Africa (Tanko, 2017). In Benin Republic, very few data are available on sesame cultivation. The work of Ajavon et al. (2015) on the socioeconomic and environmental impacts of sesame production remains one of the referenced papers in the online documentation. The latter revealed that the production of sesame is a very little developed activity in Benin. However, given the disillusionment of cotton producers, this crop is cultivated in very poor areas of the country, particularly in the north of the country. Its production allows to secure and diversify income sources for farmers and offers alternatives to satisfy their economic and food needs. This study aims to analyze the economics of sesame production in the Republic of Benin. The study intends finding answers to the following research questions: What are the costs and the returns involved in sesame production in the study area? What are the determinants of sesame output in the study area? What are the major constraints associated with the production of sesame in the study area?

Abbreviations: USD, United States Dollar; FAO, Food and Agriculture Organization.

World sesame production

Sesame ranks as the ninth amongst oleaginous crops in the world (Saha et al., 2014). Global production of sesame seed is estimated by FAO at 3.15 million tons in 2001 having risen from 1.4 million tons in the early 1960s (Chemonics International Inc, 2002). In 2008, the total world sesame production was about 3.54 million tons, grown on 7.42 million hectares (Chemonics International Inc, 2002). In 2012, the production reached 4,441,620 tons, covering 7,952,407 hectares with an average yield of 558.5 kg/ha. From 2012 to 2016, World sesame production has known a boom with a production of 12.22 million tons (Girmay, 2018).

Sesame is grown in many parts of the world on over 5 million acres (20,000 km^2). Out of the 22 countries who are the major producers of sesame in the world, 6 are in Asia, 13 in Africa and 3 in Latin America (Central and South America). Myanmar, India, and China are the highest producers, while Mali, Bangladesh, Paraguay and Benin are the least producers. FAO statistics reveal that these major sesame-producing countries together account for 92.6% of the world sesame production (UNSD, 2017; FAOSTAT, 2022). India remains the major producer of sesame accounting for more than 40% of the world's sesame area and 27% of world production. Seventy percent of the world's sesame crop is grown in Asia, with Africa growing 26% (Zerihun, 2012). Africa has become second in the world in production, increasing its production by 25% with its seven countries belonging to the largest group of sesame seeds marketers in the world, two of which are in West Africa, Nigeria with 39,800 tons and Burkina Faso with 18,107 tons (Dossa et al., 2017). The magnitude of the global market for sesame seeds is depicted in Figure 1.

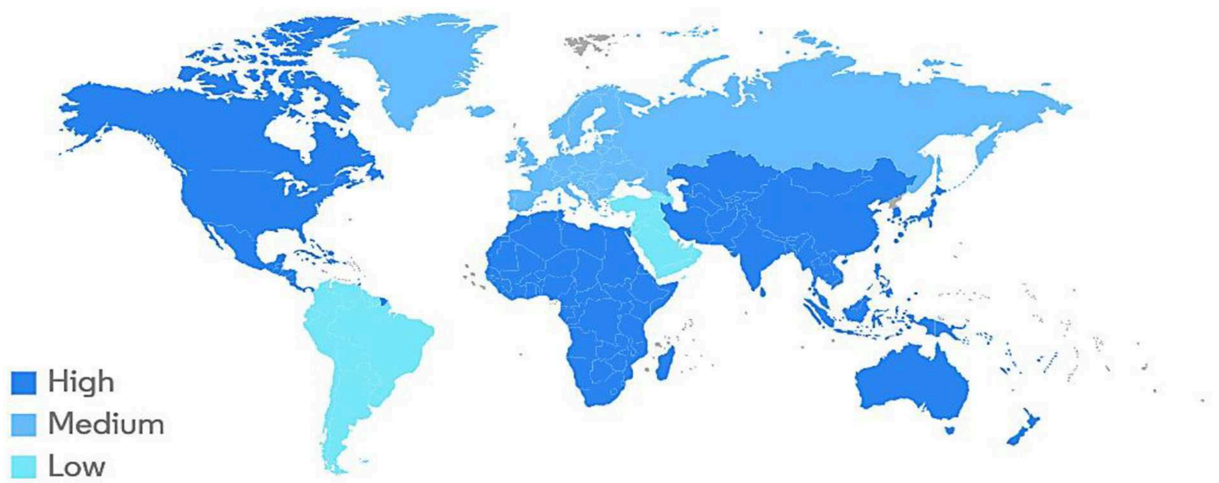

FIGURE 1
World's sesame market size (Mondor Intelligence, 2022).

Sesame production in Benin Republic

The statistics on sesame production in Benin remains obscure and rough to find because of the weak documentation on the crop. There is no scientific database showing the evolution of sesame production because the crop has always been produced by smallholders for consumption, local trade or processing.

FAOSTAT (2012) indicated that Sesame production in Benin Republic has risen from 400 tons in 1961 to 10,000 tons in 2012. This trend is showing the growing interest of sesame cultivation in Benin. The sesame export of Benin (0.2%) is still very low while the demand is becoming higher and higher. Overall, West African production of sesame is over 12,000 tons with a growing export during the last 20 years. With a yield of 900 kg/ hectare and planted area of 11,000 hectares, Benin was ranked the 22nd in the top producers of sesame in 2011.

Figure 2 shows that Benin had a peak of sesame production in 2005 (13,026 t). This peak had a dip fall as the year oversold (2006) before returning to its average from 2009. It appears that Benin has a potential for high production of sesame, but this potential is neglected by researchers and producers.

Utilization of sesame

The primary uses of the sesame seeds are as a source of oil for cooking and in the making of rolls, cracker chips of cakes, soup, spices and in jam (Abou-Gharbia et al., 2000). The young leaves may also be eaten in stews, and the dried stems may be burnt as fuel with the ash used for local soap making, but such uses are entirely subordinate to seed production (RMRDC, 2004). The oil is used as raw material to produce paints, margarine and varnishes (Nyiatagher and Ocholi, 2015). It is used in pharmacology (Anilakumar et al., 2010) and in industries with products such as perfumes, cosmetics for the skin, hair oils and soaps. Sesame oil can be used in the manufacturing of soaps, paints, perfumes, pharmaceuticals, and insecticides. Sesame meal, left after the oil is pressed from the seed is an excellent high protein source (34–50%) and used as feed for poultry and livestock (Bikoko-Pum, 2017).

In Senegal, sesame is mainly used for the sake of crop rotation and diversification to increase productivity as well as income of the rural population but also for food safety (Tunde-Akintunde et al., 2012). In Medicine, it has been proved that sesame, one of the components of sesame, protects against hepatic lesions (Nakai et al., 2003), and because of the high concentration of vitamin E, it decreases lipid peroxidation thus inhibiting the production of vascular peroxides (Nakano et al., 2003). The other use known of sesame oil is its utilization as an antibacterial mouthwash and as a laxative and in the treatment of the dryness of the nasal mucosa (Vishwanath et al., 2012).

Materials and methods

Study area

This research project was implemented in the north of Benin Republic, a country in West Africa. Benin, a narrow, north–south strip of land in West Africa, lies between latitudes 6° and 13°N, and longitudes 0° and 4°E. Benin is bounded by Togo to the west, Burkina Faso and Niger to the north, Nigeria to the east, and the Bight of Benin to the south. The capital of Benin is Porto-Novo, but the seat of government is in Cotonou, the country's largest city and economic capital. The Republic of Benin covers an area of 112,622 km², of which 22.7% is

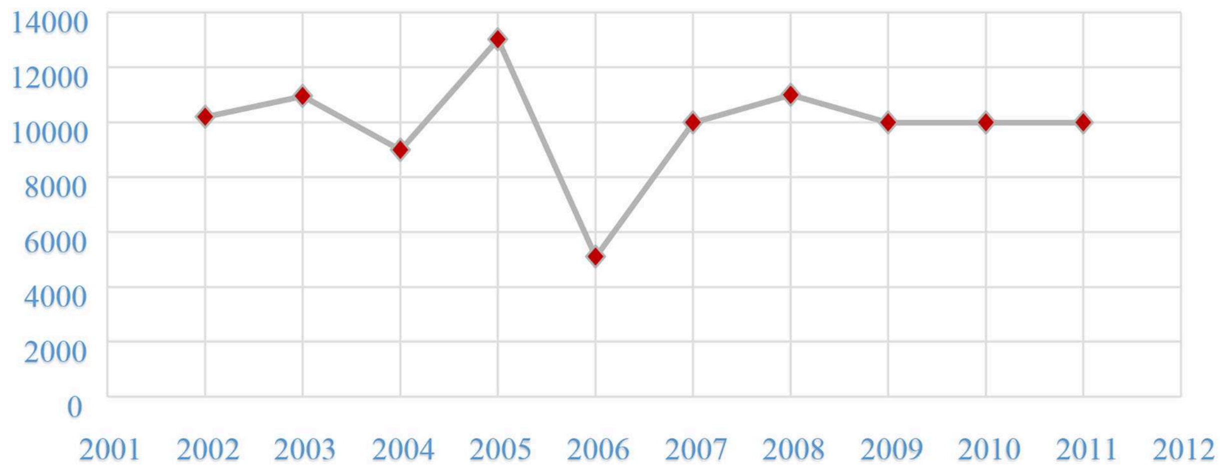

FIGURE 2
Sesame production in Benin from 2002 to 2011 (FAOSTAT, 2012).

legally protected. The population is estimated at 11 million inhabitants with a density of 57 inhabitants/km^2. Annual rainfall varies around 1,339 mm. The vegetation is mainly savannah but with some dry dense formations in the south of the country. Sesame is produced in several agro-ecological zones of Benin. However, the research focused on four (04) districts because there are many producers in these districts in addition to the fact that these districts produce the highest quantity at a national level. These districts are distributed in the two (2) departments (region) of the North of the country (districts of Djougou, Materi, Tanguiéta, and Kobli). The study area is shown in Figure 3.

Sampling procedure

A multi-stage sampling technique was adopted in the selection of respondents for this study. In the first stage, a purposive sampling was used to select four districts (of two regions) in the North of the country due to the high volume of sesame production in these districts. A random selection of villages from each of the districts was done in the second stage. From each of the four districts, three villages were chosen randomly, making a total of 12 villages. The list of farmers collected from farmer groups in these villages served as the basis for the third and final sample stage, which involved the random selection of 10 respondents from each village. This gave the study a total of 120 respondents.

Data collection

The primary data were collected with the use of a structured questionnaire designed to address the objectives of the study. This was complemented with interview schedules and group discussions. The information collected from respondents included total output of Sesame produced per annum in kilograms (kg), farmland for sesame production in hectares, quantity of seeds in kg, quantity of fertilizer used in kg, quantity of agrochemicals in liters (L), total labor utilized, unit price of inputs and outputs in USD, quantity and prices of fixed inputs such as hoes, cutlass, axes, etc. Others included information on the socio-economic characteristics of respondents such as age, marital status, household size, level of education, access to extension education, and membership to farmers' association, information about costs and return of production among others. Using a validation method termed "triangulation" with various active members of the farmer's household, we ensured that the data acquired were indeed accurate during the data collection.

Theoretical framework

Theories in this research are necessary as they provide a disciplined thought process and serve as a guide for others to follow comprehending, evaluating and critiquing the merits of a particular research (Yarger, 2006). This work was mainly based on utility theory and production theory. The combination of these two theories helps to understand and explain farmers' economic decisions in their operations.

Utility theory

The term utility is used to describe the satisfaction a person derives from the end he desired. The theory of utility assumes the rationality of individuals. In economics, an individual is "rational" if that individual maximizes utility in his/her decisions

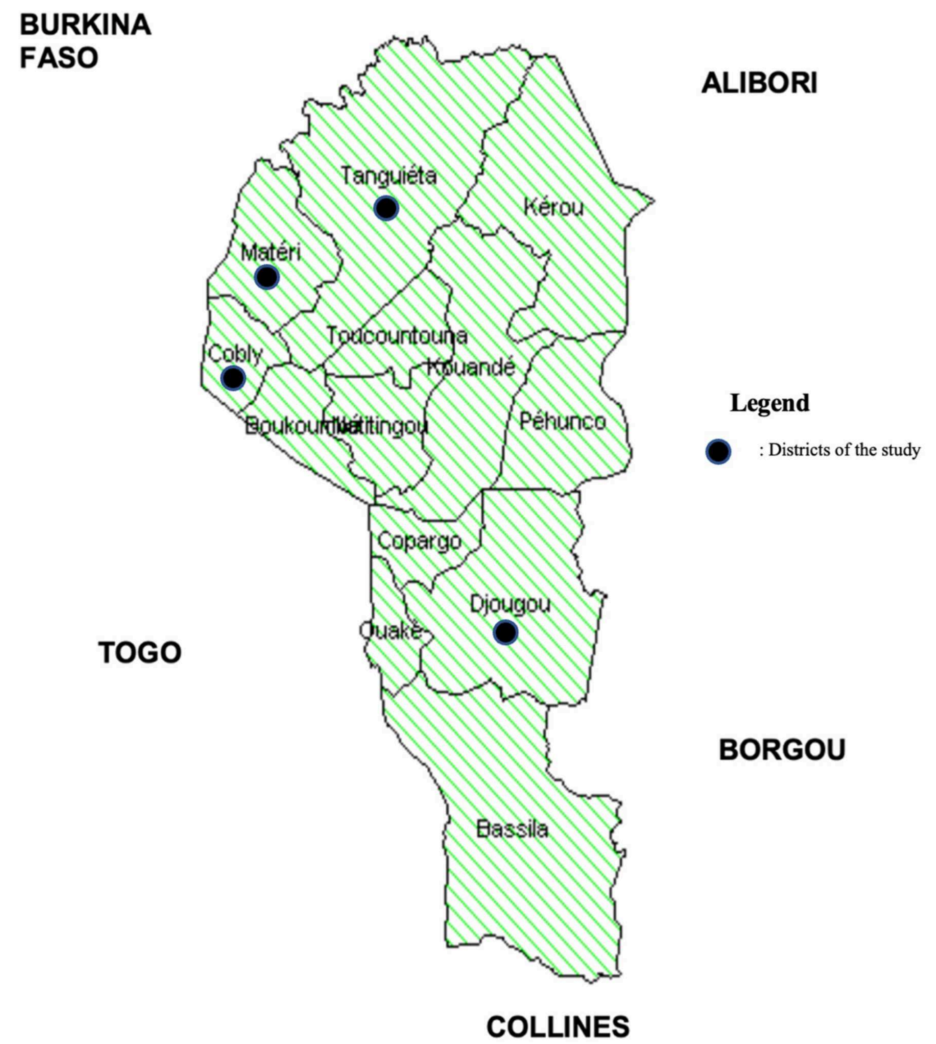

FIGURE 3
Study area.

(Mesera and Mitiku, 2015). The principles of expected utility maximization state that a rational person, when faced with a choice among a set of competing feasible alternatives, tries to select that action that will maximize his expected utility of the desired end (Yabi et al., 2016). This is in line with adoption or motivation models according to Gourieroux (1984), which state that if a person has a desire Y and if they believe that by doing X, they can achieve Y, then (assuming there is no barrier to doing X or some stronger desire than Y) he will choose X action. In our context, a rational farmer when faced with a choice among a set of competing feasible crops production, acts to select a crop that maximizes his expected utility of wealth. In rural areas, the first rational criterion of the decision to produce a crop is its profitability. Therefore, farmers will decide to cultivate sesame mainly if only it is a cash crop that will bring wealth.

Theory of production (production function)

Production function is a technical and mathematical relationship describing the manner in which the quantity of output that can be produced using different levels of inputs (Debertin, 2002). A production function can be expressed in different ways: in written form, enumerating and describing the inputs that have a bearing on the output; by listing inputs and the resulting outputs numerically in a table; depicting in the form of a graph or a diagram; and in the form of an algebraic equation. Symbolically, a production function can be written as:

$$Y = f\left(X_1, X_2, X_{3,} \ldots.., X_n\right) \quad (1)$$

Where;

Y is output,

$X_1, X_2, X_3, \ldots, X_n$ are inputs.

It however, does not differentiate between fixed and variable inputs. Since in production, fixed inputs play an important role, these are expressed as:

$$Y = f\left(\frac{X_1, X_2}{X_3} \ldots\ldots X_n\right) \quad (2)$$

Where;

Y is output,

X_1, X_2 are variable inputs,

And $X_3 \ldots\ldots X_n$ are fixed inputs.

Applying this theory in sesame production, it states that the output of sesame production depends on the quantity of inputs (fixed and variable). The best possible combination of these inputs will give the farmer the highest output of production, something which is not clearly designed for Beninese sesame production.

Analytical framework

There are various methods used to analyze profit. Each method utilizes a different approach to provide some insights into profitability. While each business might differ slightly in how it personally conducts its profit analysis, these methods are commonly used in the regular course of business. The most common ones used in agriculture are Gross margin, and Net Profit of the operation (Dédéwanou, 2010; Abu et al., 2012; Yabi et al., 2016; Dossa and Miassi, 2018). Additionally, this study aimed to identify the factors that influence sesame productivity as well as the difficulties that farmers encounter. To achieve these goals in agriculture, a semi-log OLS and the Likert scale have been utilized in numerous research (Tovignan et al., 2014; Dossa and Miassi, 2018). These studies served as the foundation for the methodology used in this study's analysis of the production's determinants and constraints. STATA v13 and SPSS v20 was used to analyze the data in this study.

Gross margin

Abu et al. (2012) have defined gross margin Analysis as a model that is used to estimate the costs, returns, profitability or loss per hectare. It is the difference between the gross returns and the total variable cost. The total revenue represents the value of the output from the farm (e.g. physical quantity of the crop multiplied by the unit price). The total cost, on the other hand is made up of the "variable" and "fixed" components. Variable cost, also called specific costs varies directly with the level of production and includes expenditure on seeds, fertilizer, chemical, hired labor, etc. (Abu et al., 2012). Fixed costs are known as overhead costs that do not vary with the level of output and consist of cash expenses (on repairs and maintenance, interest on long term loan, etc.) and non-cash adjustment (depreciation on farm tools, equipment, and machinery) (Nyiatagher and Ocholi, 2015). The Gross Margin (GM) analysis of Sesame in Benin Republic can be expressed as:

$$GM = TR - TVC \quad (3)$$

Where GM = gross margin; TR = total revenue; TVC = total variable cost.

This estimation has served as a profit index of sesame farmers in the study area. The higher the GM, the higher the profitability and vice versa.

Net profit

The net profit NP is the difference between the total revenue and the total cost as expressed in Equation 3.

$$NP = TR - TC \quad (4)$$

Where NP = net profit; TR = total revenue; TC = total cost; with $TC = TVC + TFC$.

TVC = total variable cost (labor, transportation, packaging material, purchases rent, etc. in USD).

TFC = total fixed cost (depreciation of fixed inputs such as wheelbarrows, pan, hoe, etc. in USD).

Note that depreciation can be calculated using the straight-line method as follows:

$$D = \frac{(P - R)}{N} \quad (5)$$

Where;

D = depreciation (USD); P = purchase price (USD); R = residual value (USD); N = useful life of asset (years).

Multiple regression model

The general linear model is commonly estimated using ordinary least square (OLS) which had become one of the most widely used analytical techniques in social sciences (Hutcheson, 2011). Studies have used the multiple regression model to identify the determinant of the output or the profitability of the production in agriculture (Miassi et al., 2020). Some of the statistics in social sciences are basically derived from linear models which simply means making attempt to fit a straight line to data collected. Transcendental Logarithmic (Trans log) Production Function is used to examine the magnitude and direction of the effect of independent variables on the response variable. The double-log multiple regression equation that was used for the analysis is stated as follows:

$$lnY = \beta 0 + \beta 1 lnx1 + \beta 2x2 + \beta 3x3 + \beta 4x4 + \beta 5x5 + \beta 6lnx6 + \beta 7x7 + \beta 8lnx8 + \mu t \quad (6)$$

Where Y = Net farm Income,

x_1 = Age, x_2 = Sex, x_3 = Experience, x_4 = Household size, x_5 = Education, x_6 = Land, x_7 = Crop rotation, x_8 = Capital, β0 constant or intercept, β1, β2, β3, . . . , β8 = regression coefficients that show the partial effects of the corresponding explanatory variables and μ = Error term.

Definition of the variables and their *a priori* expectation

Age

Age is a variable expressed in years. Several studies identify age as a parameter determining the profitability of agricultural production (Wacal et al., 2021; Belayneh et al., 2022). According to Sani et al. (2014), the more the producer is aged, the more he gains experience enabling him to improve the financial performance of its operations. This variable was introduced in the model to see if it has influence on the output of sesame. Age is expected to be positively related to the output because it has a significant influence on the decision-making process of farmers and the adoption of improved technology.

Gender

This refers to the sex of the respondent. It is expected that the gender affects negatively the outcome of the production.

Farming experience

It refers to the number of years the farmers have been involved in sesame cultivation. Farming experience is expected to influence output positively because increased farming experience enables farmers to take effective farm management decisions with respect to input combination or resource allocation (Soviadan et al., 2021).

Household size

This is the number of persons living together in a farmer's house. It includes the farmer, mother, children and extended relations. According to Tanko (2017), the size of the household largely depends on the status of farmers and particularly on the number of wives the farmer has. Household size is a potential source of labor and allows farmers to increase production. It is therefore expected to affect positively the output of the production.

Level of education

Education is the process of acquiring particular knowledge, developing reasoning and judgment skills. It is measured in years and can help the farmers to get the ability to understand and assess information on techniques and processes regarding the management of the operation. So, educated sesame producers will have a higher output than their uneducated counterparts (Evangilin et al., 2020). The effect of the level of education on the output would be positive.

Available land

This refers to the area of land which is measured in hectares. The area planted is a continuous variable that can influence the output of the production. Thus, sesame producers who plant in large areas, are expected to have a higher output than those who plant in a small area. Land size is expected to be positively related to sesame output following the research of Wana and Sori (2018).

Crop rotation

It is a binary variable taking the values: 1 if the producer practices crop rotation or 0 if not. This variable could have a positive effect on the output of the production, in the sense that crop rotation is said to be a very good agricultural practice that improve the yield and the productivity of farms (Gunabhagya et al., 2017; Satishkumar and Umesh, 2018).

Capital input

This variable represents the amount of fixed investment done by the farmer. This variable could have a negative effect on the output of the production, in the sense that in a short run an increase of capital input does not really impact the overall output of the production.

Net farm income

Net profits and losses from running a farm or agricultural enterprise are referred to as net farm income in the study area. It is the explained or dependent variable. The summary of the variables introduced in the model is presented in Table 1.

Fitness tests for different functional forms in the multiple regression model

Different criteria, including the value of the F-ratio and its p-value, the value of the coefficient of determination (R^2), and the number of significant variables are used to determine which function fits the data the best (Gujarati and Sangeetha, 2007). The function that fits the data the best is the one

10.3389/fsufs.2022.1015122

TABLE 1 Summary of model variables.

Variable	Type	Description
Explained variable		
lnnetfarm	Quantitative	Logarithmic form of net farm income
Explanatory variables		
lnage	Quantitative	Logarithmic form of household head age
sex	Qualitative	Dummy variable (l = male, 0 = otherwise)
exp	Quantitative	Farming experiences
hhsize	Quantitative	Household sixe
edu	Quantitative	Years of schooling of the household head
lnland	Quantitative	Logarithmic form of land operated
rot	Qualitative	Dummy variable for crop rotation (1 = yes, 0 = otherwise)
lncapital	Quantitative	Logarithmic form of capital inputs

with the lowest p-value, highest F-ratio and R^2, and most significant variables. The double-log function was ultimately chosen because, in comparison to the other four functional versions of the regression equation, it best meets the criteria. On the other hand, this indicates that the double-log function regression equation provided the greatest fit for the data.

Each explanatory variable has a very low Variance Inflation Factor (VIF) of <10.00, with a mean VIF of 1.34 (Supplementary Table 1). Therefore, there was no evidence that the data set had a multicollinearity problem.

Likert scale rating technique

In response to the difficulty of measuring character and personality traits, there are many analysis procedures appropriate for ordinal scale including Likert scale, the chi-square measure of association, Kendall Tau B and Kendall Tau C (Boone and Boone, 2012). The Likert scale technique has provided interesting results in their analysis of challenges faced by farmers (Tunde-Akintunde et al., 2012). In this study, a 5-point Likert scale rating technique was used to assess the constraints and employs an ordinal level of measurement. Numbers assigned to the items express a "greater than" relationship. The responses alternatives to various constraints were scored in a way that the response indicating the most serious constraint was given the highest score (5). Very serious (VS) = 5, Serious (S) = 4, moderately serious (MS) = 3, Least serious (LS) = 2, Not serious (NS) = 1. This is ranked using a weighted mean (X). The mean score of the respondents based on the 5-point scale is achieved thus: 5 + 4 + 3 + 2 + 1 = 15/5.

$$\frac{(SUM\ F_x)}{x} = \frac{15}{5} = 3 \qquad (7)$$

With F_x the number assigned to each Likert items and x the number of items.

Results

Socio-economic characteristics of the respondents

This section analyzed the distribution of correspondents according to gender, marital status, age, education, household size, extension contact, farm size, farming experience, membership of cooperatives, and access to credit (Table 2).

The results showed that most of the respondents were married (77.5%), dominated by males (88.3%) with a large family size. Most of the farmers were from households with 1–10 persons. The age range of the farmers was between 19–63 years meaning that sesame farmers in the study area are young, strong and active men, who are in their productive ages.

Majority (87.5%) of the farmers are literate even though they never had access to extension agents. Only 3.3% of farmers in the study area had contact with extension agents (1–3 times) during the year. In addition, 3% borrowed between 15.24 USD to 76.22 USD while 97% of the respondents had no access to credit. About 97.5% of the respondents do not belong to any cooperative society. These constraints are a big hindrance for farmers to engage in large production of sesame. However, limited access to credit, extension agents, and lack of membership in cooperative societies are the major drawbacks to sesame production in the study area. In the research area, farms tended to be 5 hectares in size on average, with fewer than 10 hectares of land being cultivated by around 70% of the respondents. A little over 91% of the respondents had more than 10 years of farming experience, whereas 82.5% had an average of 3 years producing sesame. This was a strong indicator that, in the absence of production hurdles, productivity might be boosted.

Production of sesame in Benin Republic

Sesame is typically grown in Benin on deteriorated soils with little inorganic matter. Although the vast production system predominates, the crop can sometimes benefit from intensive operations, especially in regions where cotton is grown. There is a wide range of sesame varieties: Local varieties and imported or improved varieties. Majority (80.8%) of producers use local varieties, only 19.2% cultivate improved varieties (Table 3). All the sesame varieties in North Benin have similarities regarding leaf color (green, blackish, blue, and red), plant size (1.5–2 m), flower color (rose, white, and blue), and the grain color (white and yellow). These varieties are mainly differentiated by leaf size (wide for local variety and long for improved variety), number and maturity of capsules, production cycle and yield.

TABLE 2 Distribution of the respondents based on the socio-economic characteristics.

Variable		Frequency	Variable		Frequency	Variable		Frequency
Marital status	Single	14	Household size	≤2	6	Farming experience	≤2	6
	Married	93		03–10	99		3–10	93
	Divorced	6		11–21	15		11–20	12
	Widowed	7					21+	9
	Total	120		Total	120		Total	120
Age (years)	15-35	76		Mean	7.79		Mean	2.88
	36-55	38	Contact with extension agents	Yes	04	Membership of cooperative societies	Yes	3
	46-55	14		No	116		No	117
	56+	6		Total	120		Total	120
	Total	120	Farm size	≤2	11	Access to credit	Yes	4
	Mean	34		3–11	94		No	116
Level of education	No Formal Education	12		11+	15		Total	120
				Total	120			
	Adult Education	46		Mean	5.58	Amount borrowed	Mean	45.73 USD
	Primary	39						
	Secondary	21						
	Tertiary	2						
	Total	120						

Rich, light, deep soils without being very sandy are ideal for the growth of sesame. In order to protect young plants from the damaging effects of abrupt changes in humidity and desiccation, the field must have sufficient drainage. During the first few weeks of its existence, a flood lasting a few hours is sufficient to destroy the sesame. With soils that are very infrequently flooded and have a structure that is beneficial to its production, this crop thus correlates very well to the northern portion of the Benin Republic. Sesame production is still, however, essentially extensive.

According to Table 3, 89% of the respondents inherited their farmland. Due to a growing lack of available producing land, a significant share (82%) of sesame growers are renting land. The cost of the annual land rent is generally accepted and fixed at 15.24 USD per hectare. Planting is often done on a normal prepared level ground in locations with ordinary rainfall. In regions with heavy rainfall, ridge planting is used. The delicate nature of the seedlings and the tiny size of the seeds necessitate that the seedbed be constructed with great care in order to safeguard the field from runoff and occasional flooding. It is significant to highlight that farmers in the research area do not plow; instead, they use herbicides to get rid of weeds before planting seeds.

Importance and production system of sesame in northern Benin

Maize, cotton, sesame, rice, and soybean constitute the main crops of the respondents. About 31% of respondents produce sesame as their main cash crop. According to some farmers, sesame is a cash crop capable of generating huge income because the selling price is high, and the production costs are relatively low. Sesame is produced on an average area of 1.46 hectares, with the largest sesame production area being 08 hectares. This represents about 20% of the average agricultural production area in the study area. Although it is true that these figures are not yet large enough, it should be noted that there is a gradual increase in the acreage of sesame production. According to FAOSTAT (2012), in 1996 the areas of sesame were around 1.5 on average with a total area of 3 hectares. In addition to area, average productivity has increased from 150 kg per hectare in 2005 to 318 kg in 2020, with a maximum yield of 2,000 kg per hectare. Even if the development of the sector is still low, these indicators show that with a little more effort, sesame could achieve its true potential in the Republic of Benin.

In the study area, about 99.2% of respondents do not associate sesame with other crops on their farms (Table 3). In

TABLE 3 Distribution of the respondents based on varieties, land tenure, major crops, intercropping, crop rotation, crop management.

Variable		Percentage (%)	Variable		Percentage (%)
Varieties	Local	80.8	Intercropping	Yes	0.8
	Improved	19.2		No	99.2
Land tenure	Inheritance	89.16	Crop rotation	Yes	38.3
	Gift	3.33		No	61.7
	Rented	82.5	Management of soil fertility		31.66
	Lease	4.16	Increase of the yield		66.67
Major crops	Cotton	36.7	Disease management		1,67
	Maize	28.3			
	Sesame	30.8			
	Rice	3.3			
	Soybean	0.8			
	Sesame production area (ha)	Min: 0.05			
		Max: 0.08			
		Mean:1.46			
	Sesame productivity (kg/ha)	Min: 50			
		Max: 2,000			
		Mean: 318.06			

TABLE 4 Estimated costs and returns of sesame farming in the study area.

Variables	Unit price (USD)	Average quantity/ha	Value (USD/ha)	Percentage (%)
Variable costs				
Seeds (kg)	0.76	11	8.38	12.8
Labor (Manpower)	1.82	24.5	44.81	68.4
Fertilizer (kg)	0.30	0	0	0
Herbicide (L)	2.28	2.035	4.65	7.1
Insecticide (L)	1.90	4	7.62	11.6
Total variable costs		65.47		
Fixed costs				
Cutlass		3.69		
Sprayer		11.98		
Hoe		4.08		
Knives		3.38		
Rent		15.24		
Total fixed costs		38.38		
Total cost		103.86		
Gross farm income		242.40		
Net farm income		138.54		
Return on investment		1.33		

the rest of the cases, it is in association with other crops such as peanuts, millet, sorghum, etc. Some growers find that their sesame production is not large and therefore does not require a large plot of land. So, there is no need to combine it with other crops. For other growers, they are not aware of the benefits of combining sesame with other crops. Almost half of the respondents practice crop rotation. Sesame generally comes at the head of rotation (e.g., sesame–millet–millet–sesame), or after more demanding crops (e.g., cotton–cereals–sesame; cotton–sesame–cereals; etc.). Crop rotation is a technique used by farmers, according to them, to control soil fertility, prevent soil erosion, and reduce crop disease occurrence.

Cost and return analysis

Cost of production

Table 4 displays the cost and return related to sesame production in the research area. The cost of seed, the cost of labor, the cost of herbicide, and the cost of insecticide are all included in the total variable cost. In order for sesame to benefit from the soil's stored fertilizer, cotton farmers typically plant sesame just after cotton. The overall variable cost per hectare was 65.47 USD, with labor costs accounting for the majority (68.4%) of that total (44.81 USD). The findings revealed that in the research area, sesame production is labor-intensive.

Seeds represent the second most used input for sesame production in the study area. The average cost of seed per hectare is 8.38 USD representing about 12.8% of the variable cost of production. The quality of seed is a strong determinant of the yield. Although, the imported variety of seed remains difficult to access, it has the highest productivity. Insecticide represents 11.6% of the variable cost of production. Farmers claimed that insecticide helps a lot in the fighting of insect attacks in the study area. However, insecticide is quite expensive and the quality of the ones available are not suitable for sesame crops. Herbicide had the lowest cost in terms of input 7.1%. This may be since sesame farmers do not have large areas of land. They also

TABLE 5 Regression results of factors influencing sesame output.

lnnetfarm	Coef.	Std. err.	t	$P > \|t\|$	VIF	Tolerance
lnage	0.2611747	0.1364376	1.91*	0.058	1.485	0.674
sex	−0.01294	0.1091563	-0.12^{ns}	0.906	1.213	0.824
exp	−0.0090873	0.0276695	-0.33^{ns}	0.743	1.423	0.703
hhsize	0.0180539	0.0085663	2.11**	0.037	1.543	0.648
edu	0.0138229	0.0307711	0.45^{ns}	0.654	1.201	0.833
lnland	−0.1019781	0.0764262	-1.33^{ns}	0.185	1.663	0.601
Rot	−0.2339434	0.1193862	−1.96*	0.053	1.213	0.824
lncapital	0.6994821	0.0535365	13.07***	0.000	1.056	0.947
_cons	2.964329	0.6803431	4.36***	0.000		
R-squared	=0.7266					
Adj R-squared	=0.7069					
Root MSE	=0.36916					
Prob > F	=0.0000					
Number of observations	=120					

*Significant at 10%; **significant at 5%; *** significant at 1% level of probability; ns = non-significant.

combine the herbicide application with manual weeding in the study area. This justifies the average quantity of herbicide used by sesame farmers which was only 2.03 L per hectare.

The fixed cost of production per hectare was 38.38 USD per hectare representing about 37% of total cost. This high fixed cost can be explained by the fact that most farmers in the study area rented land and the rent for a hectare of land is fixed at 15.24 USD. The other reasons could be attributed to the high cost of agricultural tools in Benin Republic. The total cost of cultivating a hectare of sesame farm was 103.86 USD.

TABLE 6 ANOVA test results.

ANOVA					
Model	Sum of squares	df	Mean square	F	Sig.
Regression	40.206176	8	5.025772	36.88	0.000
Residual	15.1268379	111	0.136277819		
Total	55.3330139	119			

Returns of production

The average quantity of yield per hectare in the study area was 318.03 kg/ha and 1,200/ha with the maximum yield being 2,000 kg/ha. This average yield is relatively low compared to other countries in West Africa like Nigeria and Burkina-Faso (1,000–1,100 kg/ha) (Nyiatagher and Ocholi, 2015). The average yield per hectare obtained 674.64 kg/ha is lower than the average yield of 1,000 kg when grown under improved management practices as reported by Tiamiyu et al. (2013). The unit price varied widely from 0.45 USD to 1.06 USD on the average during the harvesting season and scarcity periods, respectively. The gross farm income of 242.40 USD per hectare was estimated.

The net farm income of 138.54 USD per hectare was estimated. This finding implies that sesame production is profitable in the study area ($t = 23.06$, $p < 0.01$). The gross farm income covers the total cost of production, and the production of sesame could be encouraged in the study area. The profitability index was estimated to be 1.33 indicating that for each USD invested, there is a return of 1.33 USD. The null hypothesis which state that sesame production is not profitable was rejected because this result shows that sesame production is profitable in the study area.

Determinants of sesame output in the study area

The regression model performed to analyze factors that affect the output revealed that age, household size, crop rotation and capital input are significantly affecting the output of sesame (Table 5). The p-value was highly significant at 1% level ($p = 0.000$) (Table 5). From the ANOVA table (Table 6), the regression SS is 40.206 and the total SS is 55.333, which means the regression model explains about 40.206/55.333 (around 72%) of all the variability in the dataset (adjusted $R^2 = 0.70$).

TABLE 7 Challenges faced by sesame farmers in the study area.

Variables	Mean	STDV	Rank
Labor (hired)	4.50	0.635	1
Poor extension services	4.16	1.130	2
Access to land	3.83	1.275	3
Uneven ripening	3.34	1.411	4
Lack of storage facilities	3.30	1.227	5
Access to improved seed	3.29	1.299	6
Diseases	2.91	0.947	7
Marketing channels	2.83	1.145	8
High cost of hired labor	2.88	1.217	9
Pest problems	2.70	1.288	10
Family labor	2.65	1.376	11
Lack of credit	1.98	0.867	12
Drought	1.51	0.654	13

This means that independent variables introduced in the model greatly explain the dependent variable.

Age had a positive and significant ($p < 0.10$) effect on the net farm income of sesame growers in the study area. The older the farmer, the more experienced he/she is in the production of sesame in the study area. These farmers are willing to adopt new technologies that can enhance the productivity of the farm. The household size of the respondents had positive significant ($p < 0.05$) influence on the sesame farmers' net farm income due to the labor intensiveness of production. Hence, a large household size could provide a larger labor force for production. Previous analyses have shown that labor cost represents ∼68.4% of the variable costs in sesame production. Findings revealed that capital inputs also have strong and significant effect (at 1% probability level) on the net farm income of the producer. In the study area, access to land is becoming more and more difficult. Besides, sesame farmers are mostly from Niger or Burkina Faso and do not have an easy access to land. Most farmers rent the land they use for cultivation. Finally, the model demonstrated that crop rotation had a significant and negative relationship with the farmers' net farm income (at 10% probability level). This implies that farms that apply this cropping system have lower net farm income than those who do not apply it. On the counter part, the capital input had a significant and positive influence on the net farm income. Other variables like experience, age and educational level insignificantly influenced the net farm income.

According to Table 7's results, which were obtained using the Likert scale approach, constraints that have a mean value of <3 are considered minor ones, while those that have a mean value of more than 3 are major ones. Access to labor ranked first amongst the various constraints with the mean value of 4.5. Labor is a crucial input in the sesame production. Furthermore, poor extension services ranked second with mean value of 4.16 (SD = ±1.130). The aim of extension services is to enhance farmers' ability to efficiently utilize resources through the adoption of new and improved methods to maximize yield (Abu et al., 2012; Bonou-zin et al., 2019). In the study area, extension workers only work with farmers that grow national cash crops such as cotton, rice, cashew nuts etc. Majority of the sampled farmers are unable to get information about the most recent advancements in agricultural technology, pest control, and the appropriate and timely application of agricultural inputs. Difficulty of land access came in third place amongst the various constraints that farmers encounter while growing sesame. This is a severe constraint, especially because sesame production is still extensive in nature. Another reason given by sesame farmers in the study area is that, some sesame growers are non-natives from Niger, Burkina Faso and Togo who do not have access to the land. Uneven ripening is also indicated as a major problem in the maturation stage of the plant. According to farmers, this is a major problem because it makes the phytosanitary treatment and the harvest difficult. The problem is fundamentally related to the climate, soil and quality of the seed used. This problem increases labor cost during weeding and harvest periods. Lack of storage facilities was also mentioned to be a major challenge for sesame growers. The majority of farmers keep their produce in bags at home or in other places. The unavailability of improved varieties has made some farmers to completely drop or reduce the production. The yield and the quality of sesame heavily depend on the type and quality of seeds. If these issues are resolved, sesame producers will undoubtedly increase the profitability of the industry, which might encourage farmers to grow more of the crop and ultimately contribute to an improvement in the living conditions of the crop growers and marketers.

Discussion

Despite the challenging climatic circumstances of the nation, Benin Republic grows a significant amount of sesame as an alternative cash crop. The production of sesame is recently regarded as a successful farm business worldwide. This research revealed that farmers' revenue could cover the entire cost of production. Additionally, each dollar invested yields a return of 1.33 dollars, which is a sizable profit index in comparison to other crop production. These findings concur with those of Abu et al. (2012), who found that sesame production is a lucrative industry in West Africa. Additionally, Wana and Sori (2018) reported in their research that the net farm income of sesame production is positive, particularly as a result of its rising demand and price. One of the most significant finding of the study is that fertilizer is not at all applied for the production of sesame. This really significantly lowers the study's variable costs, but it may also be one of the reasons why the yield is so low when compared to that of nearby nations like Nigeria (1,000 kg/ha) and Burkina Faso (1,100 kg/ha) (Nyiatagher and Ocholi, 2015). For instance, in Morocco, the use of fertilizers has a great impact on the output of the production. However, the application of fertilizer was not a significant factor that affects the production of sesame in the study area, the regression model performed to analyze factors that affect the output revealed that age, household size, crop rotation and capital input all significantly affect sesame yield. While household size, age and capital input have a positive and significant influence on the farm's net income of sesame production, crop rotation has a positive effect on it. This result is in line with the findings of Tanko (2017) who reported that capital input and household size have a positive impact on sesame farm profitability in Nigeria. Farming operations, particularly weeding and harvesting, can benefit from the large household size that farmers have (Dossa and Miassi, 2018; Soviadan et al., 2021). This was in disagreement to Evangilin et al. (2020) findings, which showed that household size and fixed inputs doesn't significantly affect sesame production in India. Numerous studies in Africa, Europe, and Asia (Boro et al., 2014; Tovignan et al., 2014; Sene et al., 2018; Evangilin et al., 2020) however do not concur with the conclusions of this study reporting that crop rotation is essential for increasing agricultural productivity. Additionally, the result is in contradiction to that of Bonouzin et al. (2019), who found that crop rotation significantly affects yields and subsequently overall farm profitability. This result can be explained by the fact that sesame production is currently very extensive in the area. Farmers lack knowledge of the appropriate crop rotation strategy for sesame growing to produce the highest yield. However, farmers' age has a positive effect on the production. The highest yields and thus greatest income are produced by older farmers. The area's farmers have better farm management skills and are more open to the use of new technologies that could significantly enhance output (Sharmila and Kavaskar, 2017).

Sesame production in Benin Republic is hampered by a number of issues. The most significant obstacles for farmers were access to labor, access to land, uneven ripening, a lack of storage facilities, and access to improved seed among the many obstacles that were found. The vast majority of the area's sesame growers rents their farmland. Similar results were obtained by Yegbemey et al. (2014), who discovered that there has been a significant rise in the number of land renting for farming purpose in the North and Centre of the Republic of Benin. Labor unavailability is another very serious concern in the world agriculture nowadays. Particularly in Africa, this is given a great deal of significance. Sesame production, according to Wacal et al. (2021), demands a significant amount of labor. In their analysis of profitability of sesame production in Nigeria, they found that labor cost represented the major variable cost of production. According to research by Ayana (2015), Sadiq et al. (2020), and Miassi et al. (2022), there is a labor shortage in the farming industry, which drives up labor costs. India and other countries encountered similar difficulties in finding enough labor, which led to a preponderance of mechanized farming systems (Patavardhan and Leelavathi, 2013; Gunabhagya et al., 2017; Satishkumar and Umesh, 2018). With the exception of China, that deals with another challenge that is low income and wages of farm workers. According to Fischer et al. (2007), the high level of mechanization in Chinese agriculture results in a sharp decline in the requirement for labor, which lowers the market's demand for unskilled or low skilled workers.

The lack of storage facilities is revealed to be essential challenge in the production of sesame in Benin Republic. The observations are aligned with, Tiamiyu et al. (2013) report, which indicated that clean seed is packaged within polythene (BAGCO) bags and stored at home before being sold to the Nigerian buyer. This result is congruent with, Zerihun (2012) findings that the production of sesame in Ethiopia is hampered by a lack of storage facilities. Improved sesame varieties (with high yield, drought and flood resistance, and disease tolerance) would help tremendously in raising the region's overall output of sesame production.

Conclusion

The profitability of the production has positive implications for investment opportunities for individuals and corporate organizations and thus, household incomes. The high labor cost lower significantly the output of sesame. Other constraints such as labor access and availability, access to land, uneven ripening, lack of storage facilities and access to improved seed significantly hinder the production of sesame in the study area. The production will be more effective, if these challenges were addressed, thus contributing to the wellbeing of farmers. Based on the findings of this study, sesame production is a profitable venture in the study area. This value chain has enormous potential and can constitute an important cash crop for farmers. Agriculture being the pillar of the Beninese economy, this value chain could constitute an important source of national added value. Smallholder farmers will be able to increase their sesame production or highlight important business prospects as a result of this research. It is advised that organizations in charge of enhancing socioeconomic conditions, policy, food security, and rural development use the findings of this study as a guide for their planning and decision-making to improve the livelihood of smallholder farmers.

This study strongly contributes to knowledge in the field of Agricultural Economics as it highlights the economic performance of sesame production in Benin Republic. Through statistical analysis, it deepens knowledge and comprehension of sesame production. The study adds to the scant amount of previous research on sesame production in the Republic of Benin. The research also highlighted production-improving elements as well as significant production-related difficulties for farmers. The specificity in the results of this study is that in the study area farmers do not use any form of fertilizers in the production process. Furthermore, the study discovered that the most important component of the variable cost was the labor cost in the study area, which confirm previous research works that found that the production of sesame requires an important amount of labor. Building upon the findings of this research, further research could assess the agronomic and environmental interactions within the production of sesame and analyze the genetic material of local sesame seed. Such research could also investigate the perception of agricultural policymakers on the sesame production and the willingness of farmers to pay for new technologies in order to increase productivity.

There were a few problems that made this study limited. These issues include respondents refusing to respond to our questions (due to COVID-19 preventive measures), respondents misunderstanding and misinterpreting our questions (due to language barriers), respondents forgetting certain details about their production, and the reluctance of respondents to provide certain information, etc. Through effective leadership and human resource management, all of these problems were handled.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

YM and KD conducted data collection and analysis and wrote the initial drafts of the manuscript. AE participated in the results interpretation and discussion. AE and AO improve the final drafts of the paper. All authors participated in designing the study. All authors read and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.1015122/full#supplementary-material

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