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Energy inputs and crop yield relationship for sesame production in North Central Nigeria

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The energy-agriculture relationship has become a very important in view of an increasing demand for food production to meet the pressure from an ever-increasing population. For these reasons, energy use pattern, energy efficiency, and energy inputs-output relationship were determined in Sesame at the North Central Nigeria. Data were collected from 120 farmers using face to-face questionnaire method. The results indicated that total input energy use in sesame production was 2632.4 MJ, which was dominated by human labour energy (24.2%) and organic manure energy (21.1%). The output energy for sesame production was 13750.0MJ and the energy use efficiency ratio was 5.2. The proportion of renewable energy used (56%) in the surveyed Sesame farms was higher than the non-renewable energy forms (44%). The sesame production in the study area was mainly depended on indirect energy forms. Organic manure was observed to be the most important energy input influencing the yield of Sesame in the study area.

Key words: Energy, Sesame, energy efficiency, renewable energy

Introduction

The effects of agricultural activities on the environment are of growing concern. Particularly, the consumption of fossil energy, increasing energy prices, and the current debate on human influences on climate change and global warming hold a strong link to agriculture. Thus, the need for an evaluation of energy inputs use efficiency in Nigerian agriculture. This is because, efficient energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil fuels preservation and air pollution reduction (Pervanchon, 2002). In Nigeria, like any other developing countries there is lack of data on energy expenditure and returns in crop production (Abubakar and Ahmed, 2010). Even though much attention is not given to the knowledge about energy expenditure in crop production in Nigeria, the energy-agriculture relationship is becoming very

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important in view of an increasing demand for food production to meet the pressure from an ever-increasing population. For these reasons, energy use pattern, energy efficiency, and energy inputs-output relationship were determined for Sesame in order to enhance the sustainability of it production.
Sesame (*Sesamum indicum*) commonly called Benniseed in Nigeria is an important oil seed crop believed to have originated from tropical Africa. The name Sesame is used in literature world wide. Sesame can be used for confectionery, biscuits, animal feeds, fertilizers, medicinal treatment and as solvents. The spectrum of uses Benniseed had been put into is not unconnected with its unique nutritional and chemical composition. In Nigeria some small/medium level commercial ventures are now predominantly Benniseed-based (Raw Materials Research and Development Council, 2004). For instance, in some rural communities in Nasarawa state, soap is prepared from Benniseed and its by-product, by women. It is also useful in the preparation of locally brewed beverages "Kunu Ridi", Snacks "Kantu ridi" and Kulikuli" the cake obtained after extracting oil from the seed or used to prepare a local soup known as "Miyar Taushe". Sesame is produced in all the 13 Local Government Areas of Nasarawa state, but the major producing LGAs include Doma, Awe, Obi, Keana, Nasarawa and Lafia. Sesame production in Nasarawa state has increased substantially in the last five years. The average annual output in the state is about 40,000 MT ha^{-1} (Rahman, *et al*., 2007).

Materials and methods

Nasarawa state is located in the middle belt zone of the country. It lies between latitude 7^0 and 9^0 North and longitudes 7^0 and 10^0 East, and shares common boundaries with Benue state to the South, Kogi state to the West, the Federal Capital Territory (FCT), Abuja, Kaduna and Plateau State to the North-East and Taraba State to the South-East. The mean temperature range from 25^0C in October to about 36^0C in March, while rainfall varies from 131.73 mm in some places to 145 mm in others. Alluvial soils are found along the Benue Trough and their flood plain. These are always swampy in nature due to availability of water all the year round. The forest soils are rich in humus and found in most parts of the state. There are also sandy soils in some parts of the state. The three major sesame production in the states of Doma, Awe and Obi were purposively sampled. The random sampling technique was used to select 40 farmers from each LGA. A total of 120 farmers were used for the study. An interview schedule was used to obtain information on production inputs as well as outputs. The amounts of inputs were calculated on per hectare basis and these input data were converted into energy equivalent by multiplying with the coefficient of energy equivalent (Kizilaslan, 2009). For determination of energy

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equivalent coefficients, previous studies were utilized. These sources are given in Table 1. The energy equivalences of unit inputs were expressed in Mega Joule (MJ) terms. Total input equivalent can be calculated by summing of energy equivalences of all inputs in MJ terms. Data analysis was done using descriptive statistics and energy use efficiency was estimated as follows:

$$\text{Energy Efficiency} = \frac{\text{Energy Output } (\text{MJ ha}^{-1})}{\text{Energy Inputs } (\text{MJ ha}^{-1})} \qquad 1$$

The energy inputs-output relationship was estimated using production function analysis. Three functional forms (Linear, Semi-log and Cobb-Douglas) were fitted to the data and the lead model was selected base on the number of significant variable, the R^2 value and the signs of the coefficients. The implicit form of the model is specified as follows;

$Y=f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, U)$ 2

Y= Sesame yield (kg ha-^{1})

X_1= Sesame seed energy (MJ)

X_2= Machinery energy (MJ)

X_3= Pesticides energy (MJ)

X_4= Organic manure energy (MJ)

X_5= Diesel energy (MJ)

X_6= Human labour energy (MJ)

X_7= NPK fertilizer energy (MJ)

U= error term

The elasticity value for each of the energy inputs was computed using the expression

$\acute{\varepsilon}_i = MPP_i/APP_i$ ….3,

where, $\acute{\varepsilon}_i$= elasticity value for the ith energy input, MPP_i = marginal physical product for the ith energy input, and APP_i= average physical product with respect to the ith energy input. In the linear production function, the coefficients represent the MPP. However, $APP=Y/X_i$, hence, equation 3 can be re-written as $\acute{\varepsilon}_i = MPP/Y/X_i$, which becomes $MPP*X_i/Y$. X_i and Y are the means for the ith energy input and the yield of Sesame respectively. Table 1 was used to convert the inputs and output into their energy equivalents respectively.

Table 1. Energy equivalent of inputs and output in agricultural production.

Variables (MJ/Unit	**Unit**	**Energy Equivalent**	**References**
Human labour	(Man hr)	01.96	(Erdal, *et al*., 2007)
Machinery	(h)	62.70	(Erdal, *et al*., 2007)
Pesticides	(lt)	10.00	(Singh *et al.,* 1997)
Manure	(Kg)	0.30	(Hatirli, 2006)
Diesel oil	(lt)	47.8	(Pimentel 1992)
Sesame seed	(Kg)	15.2	(Akpinar, *et al*., 2009)
NPK fertilizer	(Kg)	11.76*	
Sesame yield	(Kg)	25.0	(Singh 2002)

*Explanation on the source of 11.76 MJ per Kg of NPK Fertilizer is given below.

The NPK 15:15:15 brand of compound fertilizer is used in the study area. The fertilizer blend contains Nitrogen, Phosphorus and Potassium combined in a ratio of 15:15:15 packaged in a 50kg bag. This implies that a 50kg bag of NPK 15:15:15 fertilizer contains 7.5kg of each of the elements N, P and K. According to Singh *et al* (2002), the energy equivalent of a unit (kg) of elemental N, P and K are 60.60MJ, 11.10MJ and 6.70MJ respectively. Hence, the total energy equivalent of NPK 15:15:15 in a 50 kg bag was 588MJ.This is equivalent to 11.76MJ per kg of the fertilizer.

Results and discussion

Energy use pattern in sesame production

The inputs used in sesame production and their energy equivalents, output energy equivalent, energy ratio and energy productivity are presented in Table 2. About 1.7 litres of pesticide, 45kg of NPK fertilizer were used in Sesame production on a hectare basis. The use of diesel and machine hours was 7.5 litres and 1.6 hours respectively. Furthermore, about 1850kg of organic manure and 325 man hours of labour were used per hectare. The total energy equivalent of inputs was calculated as 2632.49MJ per ha. Human labour energy had the highest share, of 24.2%. This is not unconnected to the limited usage of farm machineries for the cultural practices required for Sesame production in the study area. Organic manure energy and Diesel energy had (21.1%), and (19.1%) respectively. The Diesel-oil had a relatively high share among the inputs, due to the fact that the soil was usually tilled by ploughs. This means that less energy consuming machinery, such as smaller tractors, should be used to decrease fuel consumption during tillage operations in Sesame production. Pesticides contributed the least amount of energy (0.64%). The average yield of sesame was about 550kg ha^{-1} and its energy equivalent was calculated to be

13750.0MJ. Based on these values, the energy efficiency for the production of Sesame was 5.2. The value obtained for energy efficiency was quite higher compared to that obtained for Millet (2.4) in Nigeria by Abubakar and Ahmad (2010). The higher energy efficiency value indicated that a higher yield per hectare was obtained in the study area and the Sesame farmers are quite efficient in terms of energy use. This finding is a likely reason why Nasarawa state is noted as a major Sesame producing state in Nigeria.

Table 2. Energy consumption pattern for sesame production.

Inputs (Units)	Quantity/ha	Energy equivalents(MJ)	%
Labour (Man hr)	325.0	637.0	24.2
Machinery (h)	1.6	103.5	3.9
Pesticides (lt)	1.7	17.0	0.64
Manure (kg)	1850.0	555.0	21.1
Diesel oil (lt)	7.5	501.9	19.1
Sesame seed (kg)	19.0	288.8	10.97
NPK Fertilizer (kg)	45.0	529.2	20.1
Total energy input (MJ)		2632.4	100.0
Sesame yield (kg)	550.0	13750.0	
Energy efficiency		5.2	

Energy forms for sesame production

Direct, indirect, renewable and non-renewable energy forms used in sesame production were also investigated (Table 3). The results showed that the share of indirect input energy was 43.3% in the total energy input compared to 56.7% for the direct energy. This result showed that sesame production in the study area is mainly depended on direct energy form dominated by human labour and organic manure. On the other hand, non-renewable and renewable energy forms contributed 44% and 56% of the total energy input respectively. The proportion of renewable energy used in the surveyed sesame farms was higher than the non-renewable energy form. This implies that sesame production in the study area did not depend heavily on fossil fuels which in the long run, may lead to environmental problems such as land and water pollution. The renewable sources represent an effective alternative to fossil fuels for preventing resources depletion and for reducing pollution (Cosmi, 2003).

Table 3. Energy forms for sesame production.

Energy forms	Quantity/ha (MJ)	%
Direct[D]	1493.5	56.7
Indirect[I]	1138.9	43.3
Total energy input	2632.4	100.0
Renewable[R]	1480.8	56.0
Non- renewable[N]	1151.6	44.0
Total energy input	2632.4	100.0

[D]: human and diesel, [I]: include machinery, manure, pesticides, NPK fertilizer and seed
[R]: include human, manure and seed, [N]: include machinery, pesticides, NPK fertilizer and diesel

Relationship between energy inputs and Sesame yield

The linear model gave the best fit to the data and was selected for further analysis. The result showed that most of the variables were consistent with priori expectations. A linear relationship between energy inputs and yield was also observed by Abubakar and Ahmad (2010. The result is presented in Table 4 showed that about 88% of the variation in sesame yield was a result of the energy inputs included in the model. This result implies that sesame yield was dependent on energy inputs. The coefficient for the energy inputs for seed was significant ($P<0.01$), while those of the energy inputs for machinery energy and organic manure were significant at $P<0.05$ and $P<0.10$, respectively. However, the following energy inputs; human energy, fertilizer, pesticide and diesel gave a negative sign for their coefficients and not significant at $P=0.10$.

Table 4. Regression output for the linear production function.

Energy inputs	Coefficients	Standard Error	t-value
Constant	4132.1	4267.8	0.97
Sesame seed	24.2	2.50	9.60*
Machinery	304.6	122.9	2.5**
Pesticides	-130.1	151.3	-0.14
Manure	0.38	0.19	2.01***
labour	2.0	1.9	1.1
Diesel oil	-206.8	183.7	-1.1
NPK Fertilizer	2.8E-02	1.5	0.9
R^2	0.88		

*highly significant at 1%** significant at 5% and ***significant at 10%.

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Elasticity estimates for energy inputs

Elasticity estimates were particularly useful for determining the relationship between energy inputs and yield (Hartili, *et al*., 2006). Among the energy inputs in the linear production function model, manure energy was observed to be the most important energy input that influences the yield of Sesame in the study area (Table 5). This was closely followed by human labour energy. 1 % increase in manure and human labour energy would lead approximately 1.3%, and 1.2% increased in the yield of sesame respectively. Diesel on the other hand was the energy input that least influences the yield of sesame.

Table 5. Elasticity estimates for energy inputs in sesame production.

Energy inputs	Elasticity values
Sesame seed	0.82
Machinery	0.88
Pesticides	-0.40
Manure	1.27
labour	1.18
Diesel	-2.82
NPK fertilizer	1.0E-03

The efficiency of energy using in sesame production was very high, and renewable energy sources, especially organic manure and human labour that very essential for the sustainability of sesame production in the study area. Therefore, the sesame farmers are needed to sensitize on the availability of affordable industrially manufactured organic manure such as Rootliser, Nomau and Fertiplus. Furthermore, less energy consuming machinery should be used for soil tillage, and carried out for other crops production in Nigeria.

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