STUDY ON TECHNICAL EFFICIENCY AND PROFITABILITY OF RAIN-FED SESAME PRODUCTION IN MAGWAY TOWNSHIP

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STUDY ON TECHNICAL EFFICIENCY AND PROFITABILITY OF RAIN-FED SESAME PRODUCTION IN MAGWAY TOWNSHIP

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The thesis attached here to, entitled **"STUDY ON TECHNICAL EFFICIENCY AND PROFITABILITY OF RAIN-FED SESAME PRODUCTION IN MAGWAY TOWNSHIP"** was prepared and submitted by Thuzar Linn under the direction of the chairperson of the candidate supervisory committee and has been approved by all members of that committee and the board of examiners as a partial fulfillment of the requirements for the degree of **MASTER OF AGRICULTURAL SCIENCE (AGRICULTURAL ECONOMICS)**.

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This thesis represents the original work of the author, except where otherwise stated. It has not been submitted previously for a degree at any other University.

Date ---------------   -----------------------------

Thuzar Linn

DEDICATED TO MY BELOVED PARENTS,

U LU HLA AND DAW KHIN CHO

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ABSTRACT

Sesame is economically important for edible oil and as an export crop in Myanmar. This study was mainly conducted to assess and compare the household income and profitability of sesame production among different farm size groups, and to estimate the existing production proficiency of sample farmers in given input use through the technical efficiency (TE) measurement. Household level survey was conducted in December, 2011 and January, 2012. The primary data was collected from 130 sample rain-fed sesame farmers from 4 villages in Magway Township by using simple random sampling method. Descriptive and inferential statistics, economic analysis and production frontier analysis (FRONTIER 4.1) were used to catch up the objectives of the study.

Average education level and average farm experience of large farm household heads were the highest among three different farm size groups. The major source of income for overall households was crop income (79% of total household income) and rain-fed sesame income contributed to 46% of the total household income. Black sesame (*Samon*) and white sesame (*Ba Pan*) were grown more than other varieties by the sample farm households in the study area. The benefit-cost ratios of small, medium and large farm households were 1.58, 1.70 and 2.05, respectively for rain-fed sesame production in the study area. The benefit-cost ratio of black sesame farmers (1.87) was higher than that of white sesame farmers (1.76). In efficiency measurement, the coefficient of manure and human labor were positive and significant factors in rain-fed sesame production for all sample farm households indicating that the sesame yield can be increased by using more of these inputs. The estimated value of animal labor was negative and statistically significant indicating that the sample farmers in the study area overused the animal labor in rain-fed sesame production. The estimated value of the coefficient of manure was positive and statistically significant in black sesame production. The yield of black sesame will be increased by using additional manure. The education level and experience in farming of black sesame farmers had negative impact on inefficiency implying that the farmers with higher education level and experience were more efficient in black sesame production than the farmers with lower education level and experience. The coefficient of human labor was positive and statistically significant on white sesame productivity indicating that the yield of white sesame can be increased with the use of additional human labor. In inefficiency model, farm size was a negative and significant factor meaning that the farmers with larger farm size were more efficient in white sesame production than the farmers with small farm size. For all sample farmers, mean technical efficiency (TE) had been estimated as 0.68, implying that in average, the sample farmers tended to realize 68% of their technical abilities. The mean TE of small, medium and large farm households was 0.60, 0.65 and 0.74 respectively. According to mean TE, large farm households were more efficient in sesame production than the other two. The black sesame farm households (63 farm households) had mean TE of 0.67 and white sesame farm households (67 farm households) had mean TE of 0.66. The constraint pointed out that it is effective extension services are needed for sesame farmers in the study area. Hence, the government should strengthen the extension mechanism to improve farmers' practices through extension services and training programs, so that farmers can apply available agricultural technology more efficiently. The constraint analysis pointed out that the credit for farmers received from MADB was very low. Therefore, The INGOs and NGOs should provide the credit for sesame farmers for increasing profitability and technical efficiency in sesame production.

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LIST OF ABBREVIATIONS

Amd	= Animal day
BCR	= Benefit-Cost Ratio
DOA	= Department of Agriculture
FAO	= Food and Agriculture Organization
FAOSTAT	= Statistics of Food and Agriculture Organization
ha	= Hectare
HH	= Household
Kg	= Kilogram
MOAI	= Ministry of Agriculture and Irrigation
MLE	= Maximum Likelihood Estimation
MT	= Metric Ton
OLS	= Ordinary Least Square

LIST OF CONVERSION FACTORS

1 Basket of Sesame	=	24.49 kilograms
1 Ton	=	1000 kilograms
1 Ton	=	2 cartloads of cow dung
1 Hectare	=	2.471 acres

CHAPTER I
INTRODUCTION

Myanmar is an agri-based country and agriculture sector remains important to the country's economy. The agriculture sector will continue to be essential for food production with the growing population as well as for the country to occupy a large part of the export earnings. Growth in agricultural sector is necessary to increase food availability and sustain the economic development process continuously. The main objective of the Ministry of Agriculture and Irrigation (MOAI) with a view to improve the agriculture sector is to increase the incomes of the farmers through the increase of crop production. Sufficiency of edible oil is one of the important needs of the country. To be fulfill this need, it is necessary to increase the production of oilseed crops.

Third to paddy and pulses in the percentage shares of total sown area in Myanmar is oilseed crop. In 2009, paddy achieved 34% and was followed by pulses of 19% and oilseed of 16% in the total crop sown area (Figure 1.1) (MOAI 2011). In order to increase crop production, expansion of area and technology of oilseed crops is needed for local consumption and to generate more surpluses for the increase of export earnings. There are many kinds of oilseed crops such as groundnut, sesame, sunflower, mustard and niger. Among them, sesame was the largest sown area nearly about 50% of the oilseed crops and followed by the groundnut, 23% (Figure 1.2) (MOAI 2011).

Sesame (*Sesamum indicum*), an ancient oilseed, is one of the oldest cultivated plants in the world. This warm-season annual crop is primarily adapted to areas with the long growing seasons and well-drained soils. It has spread from its center of origin in Iraq to many parts of the world. Sesame has been grown in Myanmar since King Era, 1044 A.D. Sesame is economically important not only for producing edible oil but also for export crops. However, sesame yield is very low with the high risk of drought in the "Ya" land of central dry zone area. The sesame crop is also called gambling crop because its production depends on the drought or erratic rainfall at harvest time which results in low yield per unit area.

In the world, India occupied the highest harvested area which was 24.28% of the world sesame harvested area and Myanmar was the second. World's sesame production was 3,976.97 thousand MT of which Asia's sesame production was 2,489.52 thousand MT which was 62.60% in world total sesame production and yield was 0.56 MT per hectare in 2009. Myanmar occupied the highest sesame production (867.52 thousand MT) of Asia and sesame yield was 0.55 MT per hectare. Myanmar was followed by India as the sesame production. In terms of sesame production, Myanmar occupied 21.81% in the world and 34.84% in Asia (Table 1.1) (FAO 2011).

Over 90% of total sesame sown area was found in the central plains of Magway, Mandalay and Sagaing Region in 2010. Magway Region contributed about 548.93 thousand hectares (34.62%) of the national total area of sesame cultivation as the largest percentage shares of sown area of oilseed crops in Myanmar. As the second largest sown area of sesame production was found in Mandalay Region contributed about sesame area of 496.92 thousand hectares (31.34%) and Sagaing Region occupied the third largest sown area, contributed about 378.86 thousand hectares (23.9%) of total sesame sown area (Table 1.2) (DOA 2011).

Table 1.1 Sesame production in Myanmar and neighboring countries (2009)

Country	Harvested Area ('000 ha)	Yield (MT/ha)	Production ('000 MT)
World	7,700.28	0.51	3,976.97
Asia	4,411.00	0.56	2,489.52
Myanmar	1,570.00	0.55	867.52
India	1,870.00	0.35	657.00
China	476.91	0.13	622.91
Thailand	59.27	0.78	46.04
Bangladesh	35.55	0.91	32.31
Cambodia	400.00	0.78	31.00
Viet Nam	46.00	0.52	24.00
Lao PDR	11.17	0.69	7.66

Source: FAO (2011)

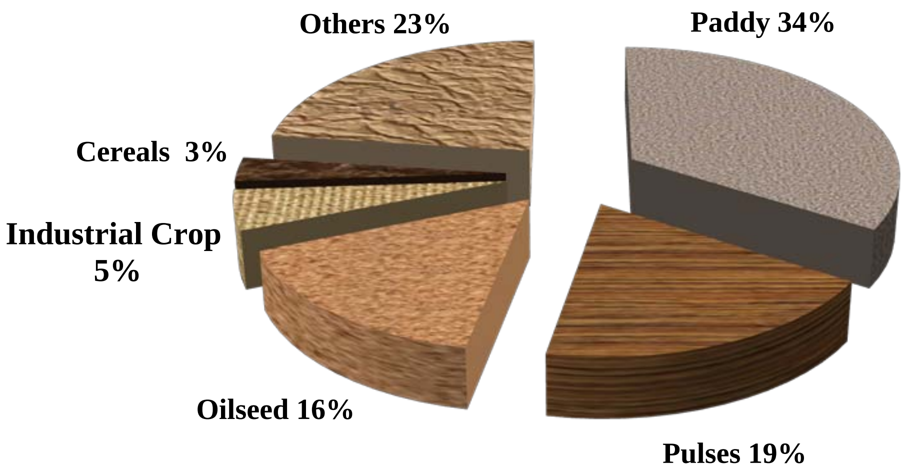


Figure1. 1 Percentage shares of sown area for major crops in Myanmar

Source: MOAI (2011)

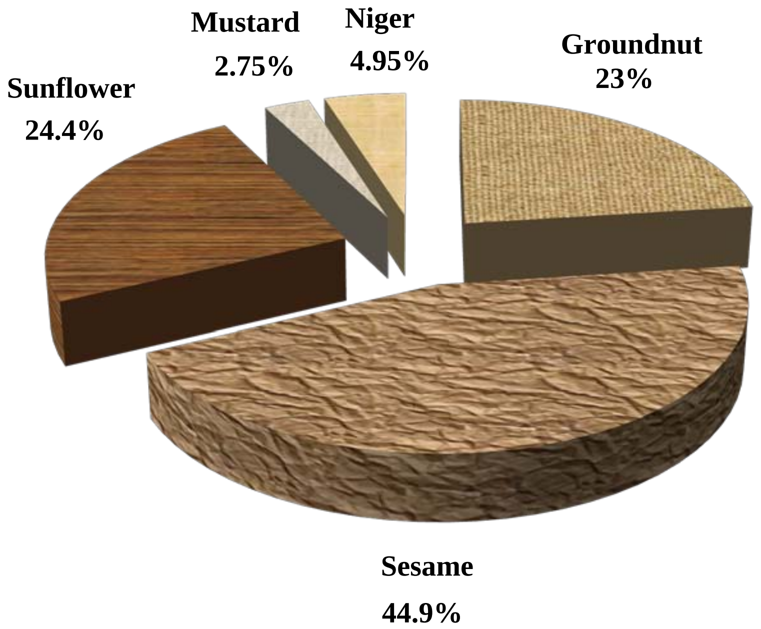


Figure 1. 2 Percentage shares of sown area for oilseed crops in Myanmar

Source: MOAI (2011)

Table 1.2 Sown area, harvested area, yield and production of sesame in different Regions of Myanmar (2010-11)

S.N.	Region	Sown Area (‘000 ha)	Harvested Area (‘000 ha)	Yield (MT/ha)	Production (‘000 MT)
1	Kachin	10.03	10.03	0.65	6.99
2	Kayah	7.25	7.25	0.62	4.31
3	Karen	16.56	16.56	0.74	12.38
4	Chin	3.09	3.09	0.51	1.41
5	Sagaing	378.86	377.60	0.77	233.82
6	Tanintharyi	0.67	0.67	0.32	0.22
7	Bago(East)	22.15	22.15	0.62	13.57
8	Bago(West)	58.39	58.38	0.66	37.86
9	Magway	548.93	548.93	0.79	337.76
10	Mandalay	496.92	496.75	0.55	170.65
11	Mon	6.71	6.71	0.59	4.54
12	Rakhine	2.00	1.99	0.48	1.00
13	Yangon	2.04	2.04	0.54	1.22
14	Shan (South)	10.79	10.79	0.55	5.55
15	Shan (North)	4.75	4.75	0.71	3.95
16	Shan (East)	3.10	3.10	0.59	1.79
17	Ayeyarwady	13.18	13.18	0.80	10.93
Union Total		1,585.42	1,583.98	0.54	847.96

Source: DOA (2011)

1.1 Area, Yield and Production of Sesame

In Myanmar, the sown area of sesame was gradually increased from 1,276 thousand hectares in 1995-1996 to 1,585 thousand hectares in 2010-2011. However, in 2005-2006, the sown area was unexpectedly decreased to 1,338 thousand hectares. (Figure 1.3) (MOAI 2011). Yield per hectare of sesame was increased about 0.54 MT per hectare in 2010-2011 (Figure 1.3) (MOAI 2011).

In 2009-2010, the sown area of rain-fed sesame was accounted for about 1,163.61 thousand hectares, which was 73.46% of the total sesame sown area. The total production of rain-fed sesame was 528.51 thousand MT which was 62.33% of total sesame production and yield was 0.45 MT per hectare. Post-monsoon or winter sesame sown with residual moisture available at that juncture was grown about 65.43 thousand hectares which was 22.5% of the total sown area. Since the yield of winter sesame was 0.94 MT per hectare, it was produced about 528 thousand MT which was 30.51% of the total production. The sown area of irrigated sesame was about 356.38 thousand hectares which was 4.13% of the total sesame sown area. It was produced 258.88 thousand MT which was 7.14% of the total production and yield was 0.73 MT per hectare. The sown area and harvested area of rain-fed sesame was higher than those of the winter and summer sesame (Table 1.3) (DOA 2011).

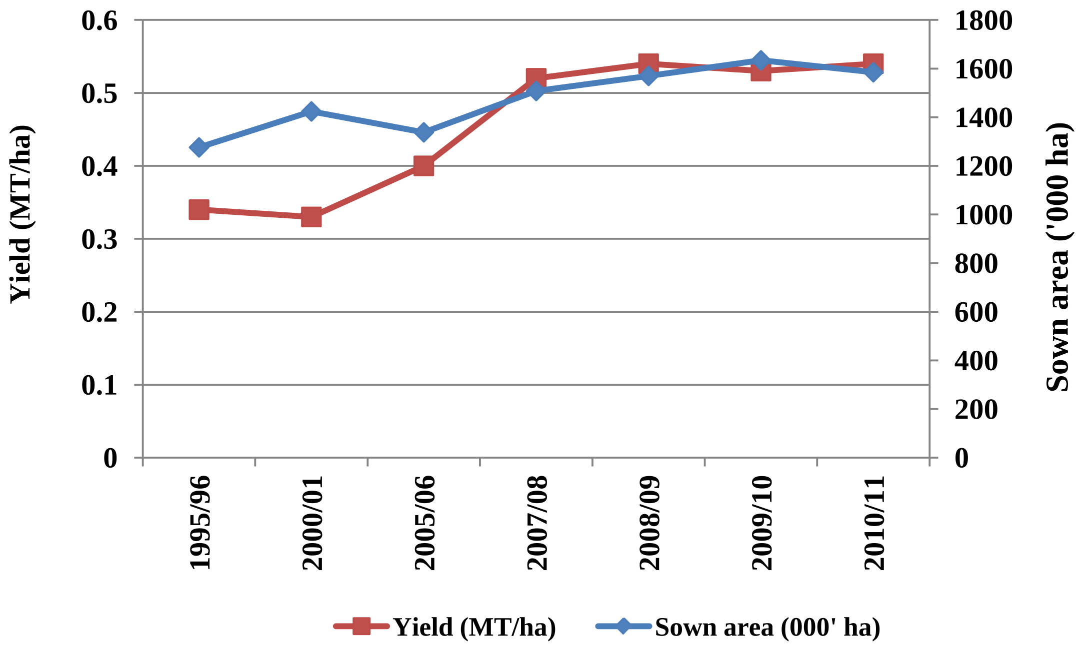


Figure 1. 3 Sown area and yield of sesame in Myanmar (1995/96 to 2010/2011)

Source: MOAI (2011)

Table 1.3 Sown area, harvested area, yield and production of sesame for three various seasons in Myanmar (2009-2010)

Sesame	Sown Area ('000 ha)	Harvested Area ('000 ha)	Yield (MT/ha)	Production ('000 MT)
Pre-monsoon Sesame (Summer Sesame)	356.38	355.67	0.73	258.88
Monsoon Sesame (Rainfed Sesame)	1,163.61	1,163.57	0.45	528.51
Post-monsoon Sesame (Winter Sesame)	65.43	64.73	0.94	60.57

Source: DOA (2011)

1.2 Export Status of Myanma Sesame

The country has relied on agriculture sector (crop, livestock, fishery and forestry) for export earnings. The major export commodities of agriculture sector are rice, black gram, green gram, pigeon pea, maize and sesame. Myanmar sesame is exported to China, Japan, Bangladesh, Singapore, Malaysia and the Middle East. The intake of foreign markets depends on the colors of the sesame and among the cultivated strains of “black Theikpan”, “Ordinary black sesame”, “White sesame”, “red sesame”, the cultivars, “black Theikpan” fetched the highest prices in Japanese markets. Myanma sesame export was fluctuated from 1995 to 2010 as shown in Figure 1.4 (FAO 2011).

Myanma sesame was exported to other countries in 2011-2012 as shown in Table 1.4. Japan was the major sesame importing country from Myanmar and imported about 13.97 thousand MT. Second and third major importing countries for Myanma sesame were Republic of Korea and Singapore and imported about 11.73 thousand MT and 5.11 thousand MT respectively. China and Malaysia imported Myanmar sesame about 2.39 thousand MT and 2.25 thousand MT respectively. Myanmar also exported sesame to Vietnam, Thailand, Indonesia, India and United Arab Emirates. In terms of export earnings, Myanmar earned nearly 59 million US$ from sesame export in 2011-2012. In the world’s sesame export, Myanmar occupied 4.04% of the total world’s export and 3.21% of the total world’s sesame export earning as shown in Table 1.5 (FAO 2010). Myanmar stood as the seventh country in exporting sesame in the world.

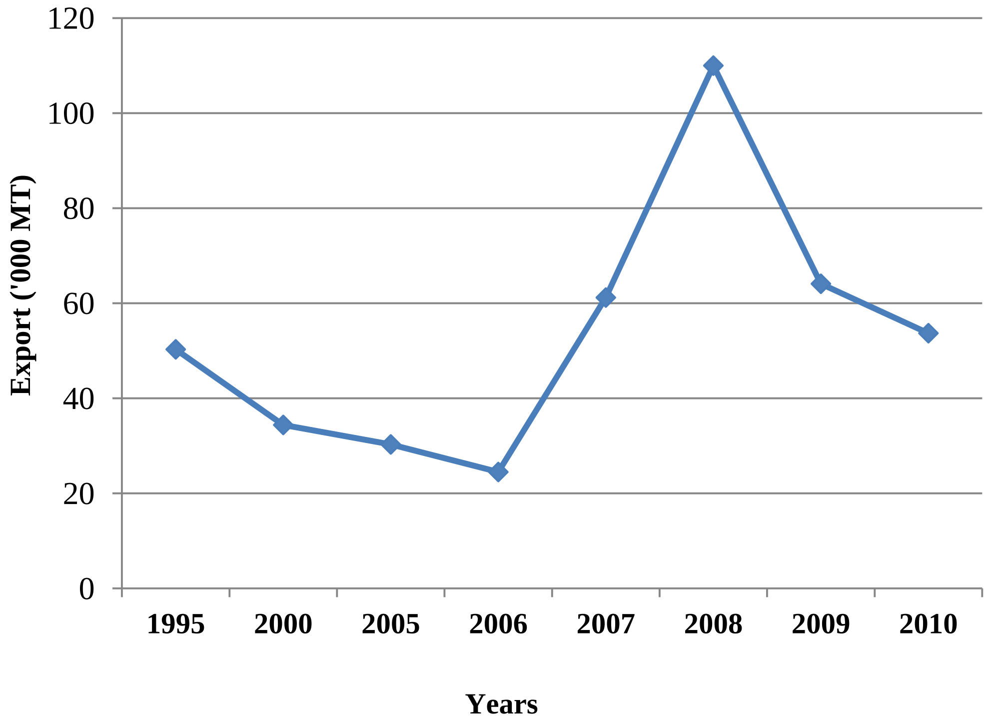


Figure 1. 4 Export of sesame from Myanmar (1995 to 2010)

Source: FAO (2011)

Table 1.4 Trading partners of Myanma sesame (2011-2012)

Country	Export amount ('000 MT)	Export value (million US$)
Japan	13.97	23.65
Republic of Korea	11.73	19.69
Singapore	5.11	7.69
China	2.39	3.43
Malaysia	2.25	3.57
Vietnam	0.38	0.58
Thailand	0.95	0.18
Indonesia	0.06	0.09
United Arab Emirates	0.02	0.03
India	0.02	0.03

Source: Custom data (2011-2012)

Table 1.5 World sesame export (2010)

Country	Export quantity ('000 MT)	Export Value (million US$)
World	1,327.69	1,662.16
India	321.77	455.43
Ethiopia	228.03	293.56
Sudan (former)	138.00	182.00
Nigeria	140.80	139.00
China	33.15	60.38
Burkina Faso	61.30	55.79
Myanmar	53.70	53.35
United Republic of Tanzania	65.70	50.10
Paraguay	35.80	45.00
Guatemala	23.14	33.76

Source: FAO (2011)

1.3 Problem Statement

Sesame seed, one of the important oilseeds and an export crop, is produced for its oil and is also used as a flavoring agent. Sesame oil is one of the most stable vegetable oils, with long shelf life, because of the high level of natural antioxidants. Sesame is very drought-tolerant. It has been called a survivor crop, with an ability to grow where most crops fail. Sesame plays an important role in Myanmar as well as global commerce. Sesame is inseparable with Myanmar people, Myanmar culture and Myanmar tradition.

Socio-economic characteristics such as education and experience of farmers used to influence on the yield, production and sown area of sesame. The different farm size groups (small, medium and large farm size groups) used to be different in input utilization in sesame production. Sesame production also used to fluctuate in the dry zone area because sesame is a gambling crop.

In the dry zone area, majority of farmers used to depend mainly on crop income followed by selling goods income, migration income, government staff or company staff income and causal labor income. Oilseed crops and pulses are major growing crops in the dry zone area. In addition, sesame income used to influence on crop income. Income and profitability of different farm size groups used to be different according to their production costs and price received.

In the view of sesame production, 847 thousand MT of sesame was produced in 2010-2011, mainly in Magway, Mandalay and Sagaing Regions and it was a rising trend since 2005-06. The growth rate of sesame yield gradually increased between 2005 and 2011 (Table 1.5). The national target yield of sesame is 1.21 MT per hectare. However, the farmer's actual yield is lower than the maximum potential yield. Therefore, it is needed to investigate the difference between the farmer's actual yield and maximum potential yield.

To increase crop production, there are three possible ways such as increasing crop sown area, developing and adopting new production technologies and utilizing the available resources more efficiently. The two former ways may need considerable time, costs and other considerations for both farmers and policy makers. The production efficiency measurement of the individual farmer becomes one of the suitable approaches for the study area. Therefore, this was carried out to study how the farmers use their resources efficiently in sesame production.

Table 1.5 Changes of sesame sown area, yield and production in Myanmar

Items	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
Sown area ('000 ha)	1338	1443	1508	1507	1634	1585
Growth rate (%)		7.84	6	-0.07	8.43	-2.99
Yield (MT/ha)	0.4	0.48	0.52	0.54	0.53	0.54
Growth rate (%)		8.3	15	3.80	1.85	1.89
Production ('000 MT)	504	690	781	853	868	847
Growth rate (%)		13.19	27.48	9.22	1.76	-2.42

Source: MOAI (2011)

1.4 Objectives

The overall objective of the study is to know whether the farmers in the study area are technically efficient in sesame production or not. The specific objectives are:

(1) To study socio-economic characteristics of sample rain-fed sesame farmers and the input utilization of different farm size groups (small, medium and large farm size) in the study area;

(2) To assess and compare household income and the profitability among different farm size groups in rain-fed sesame production and between black sesame and white sesame production;

(3) To estimate the existing production proficiency of rain-fed sesame farmers and of black sesame and white sesame farmers in given input use through technical efficiency measurement; and

(4) To identify farm specific characteristics that may affect the technical inefficiency.

1.5 Hypothesis

Based on the objectives, the hypotheses for this study were formulated.

(1) There are significant differences in the input utilization among the sample rain-fed sesame farmers.

(2) Farmers are profitable from rain-fed sesame production in the study area.

(3) Socio-economic characteristics of sample rain-fed sesame farmers and farm-specific characteristics do reflect the technical inefficiency.

CHAPTER II

LITERATURE REVIEW

2.1 Theoretical Framework for Technical Efficiency

2.1.1 Definitions of Efficiency

Technical efficiency, as stated in the study, is defined as the capacity of producers or farmers to maximize output from a given set of inputs (Chaudhry 1979 and Moock 1981). Allocative and economic efficiencies can be defined as the ability to produce a given level of output at a lowest cost. In theory, a firm's efficiency is usually judged by comparing the observed situation with some well-behaved efficiency norm (Pothisuwan 1997).

2.1.2 The Stochastic Frontier Production Function

Aigner and Chu (1968) considered the estimation of a parametric frontier production function of Cobb-Douglas form, using data on a sample of N firms. The model is defined by

$$Ln(y_i) = x_i\beta - u_i \qquad , i=1,2,\ldots,N \qquad (2.1.3)$$

where $Ln(y_i)$ is the logarithm of the output for the i^{th} firm;

x_i is a (K+1)-row vector, whose first element is "i" and the remaining elements are the logarithms of the K-input quantities used by the i^{th} firm;

$\beta = (\beta_0, \beta_1, \ldots, \beta_k)$ is a (K+1) - column vector of unknown parameters to be estimated; and

u_i is non-negative random variable associated with technical inefficiency in production of firms in the industry involved.

The ratio of the observed output for the i^{th} firm, relative to the potential output, defined by the frontier function, given the input vector, x_i, is used to define the technical efficiency of the i^{th} firm:

$$TE_i = \frac{y_i}{\exp(x_i\,\beta)} = \frac{\exp(x_i\,\beta - u_i)}{\exp(x_i\,\beta)} = \exp(-u_i) \qquad (2.1.4)$$

This measure is an output oriented measure of technical efficiency, which takes a value between zero and one. It indicates the magnitude of the output of the i^{th} firm relative to the output that could be produced by a fully-efficient firm using the same input vector.

Aigner, et al. (1977), and Meeusen and Broeck (1977) independently proposed the stochastic frontier production function, in which an additional random error, v_i, is added to the non-negative random variable, u_i in the equation (2.1.3) to provide:

$$Ln(y_i) = x_i\beta+v_i-u_i \qquad , i = 1,2,\ldots,N \qquad (2.1.5)$$

The random error, v_i, accounts for measurement error and other random factors, such as the effects of weather, strikes, luck, etc., on the value of output variable, together with the combined effects of unspecified input variables in the production function. Aigner, et al. (1977) assumed that the v_is were independent and identically distributed (i.i.d.) normal random variables with mean zero and constant variance σ_v^2, independent of the u_i, which were assumed to be i.i.d. exponential or half-normal random variables.

The model defined by the equation 2.1.5 is called the stochastic frontier function because the output values are bounded by the stochastic (random) variable, exp (x_i β + v). The random error, v_i, can be positive or negative and so the stochastic frontier outputs vary with the deterministic part of the frontier model, exp (x_i β).

2.1.3 Maximum-Likelihood Estimation

The parameters of the stochastic frontier production function, defined by equation 2.1.5, can be estimated using either maximum-likelihood (ML) method or using a variant of the OLS method. The OLS approach is not as computationally demanding as the ML method, which requires numerical maximization of the likelihood function. FRONTIER program (Coelli 1992, 1996a) automates the ML method for estimation of the parameters of stochastic frontier models.

The ML estimator is asymptotically more efficient than the OLS estimator. ML estimator was found to be significantly better than the OLS estimator when the contribution of the technical inefficiency effects on the total variance term is large. Aigner, et al. (1977) derived the log-likelihood function for the model, defined by the equation 2.1.5, in which the u_is are assumed to be i.i.d. truncations (at zero) of a N(0, σ^2) random variable, independent of the v_is which are assumed to be i.i.d. N(0, σ_v^2). Aigner, Lovell and Schmidt (1977) expressed the likelihood function in terms of the two variance parameters, $\sigma_s^2 = \sigma^2 + \sigma_v^2$ and $\lambda = \sigma/ \sigma_v$. Battese and Corra (1977) suggested that the parameter, $\gamma = \sigma^2/ \sigma_s^2$, be used because it has a value between zero and one. The ML estimates of β, σ_s^2 and γ are obtained by finding the maximum of the log-likelihood function.

2.1.4 Productivity and Frontier Function

Ali and Chaudhry (1990) used to measure the technical, allocative and economic efficiencies in terms of input-output space presented in Figure 2.1. The curve TPP_a (total physical productivity) represents the average function that is usually estimated by using OLS, while the curve TPP_m represents the maximum possible total output as input X is increased. This is known as the frontier production function. All firms that produce below TPP_m are considered technically inefficient because of giving less output at a given level of input. The profit maximization criterion suggests that producers will utilize input level at X_1 (where the marginal value product of X is equal to its price, P_x) and will produce the technically and allocatively efficient output at Y_1. The firm which uses X_2 and produces Y_2 (represented by point C) is technically and allocatively inefficient. Technical efficiency is defined as the ratio of a firm's actual output to the technically maximum possible output at a given level of input and can be written as:

$$TE = Y_2 / Y_3$$

Allocative efficiency is expressed as the ratio of the technically maximum possible output at the farmer's level of input to the output obtainable at the optimum level of input that can be written as:

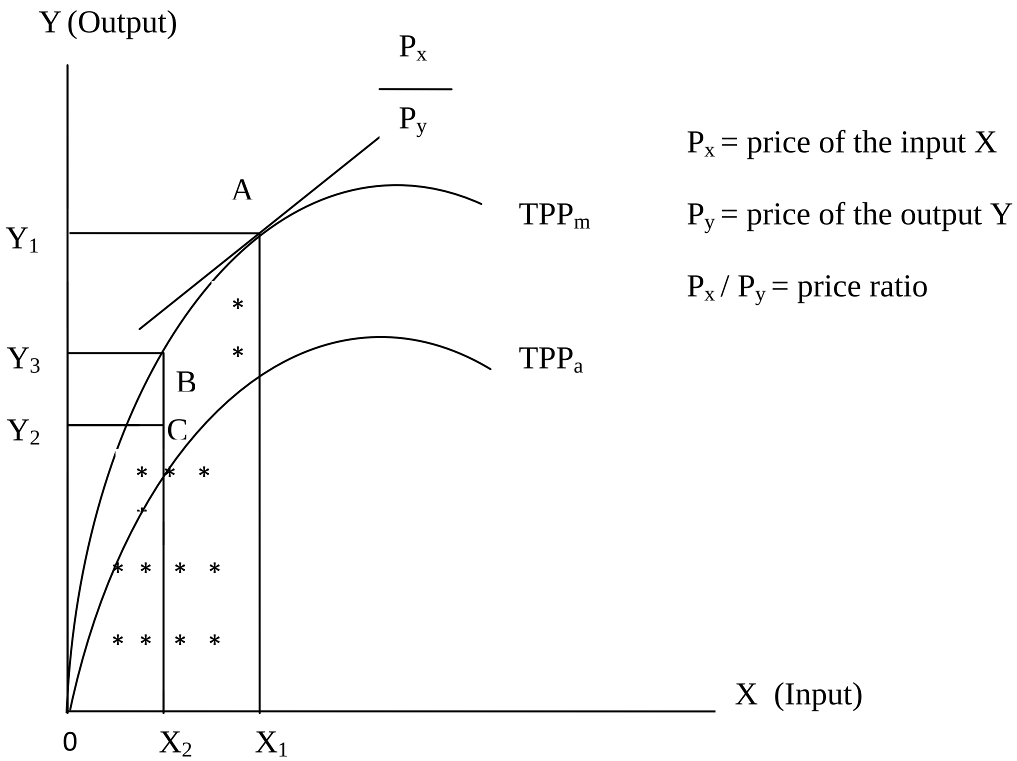
$$AE = Y_3 / Y_1$$

Economic efficiency is the product of technical and allocative efficiencies that can be written as:

$$EE = (Y_2 / Y_3)\ (Y_3 / Y_1) = Y_2 / Y_1$$

Therefore, the technical, allocative and economic inefficiencies are measured as $(1-Y_2 / Y_3)$, $(1-Y_3 / Y_1)$ and $(1-Y_2 / Y_1)$, respectively.

Hence, efficiency can be measured only if there is frontier function with which to compare an average function. The frontier function is the maximum output obtainable from various input vectors at a certain level of technology. There are various approaches measuring and estimating efficiency. In this study, stochastic production frontier will be applied using Maximum Likelihood Estimation to estimate the technical efficiency of the sesame farmers in the selected township.



$TE = Y_2 / Y_3$ $AE = Y_3 / Y_1$ $EE = (Y_2 / Y_3)(Y_3 / Y_1) = Y_2 / Y_1$

The technical, allocative and economic inefficiencies were measured as

Figure 2.1 Technical, allocative and economic efficiencies in terms of input-output space (Ali and Chaudhry 1990)

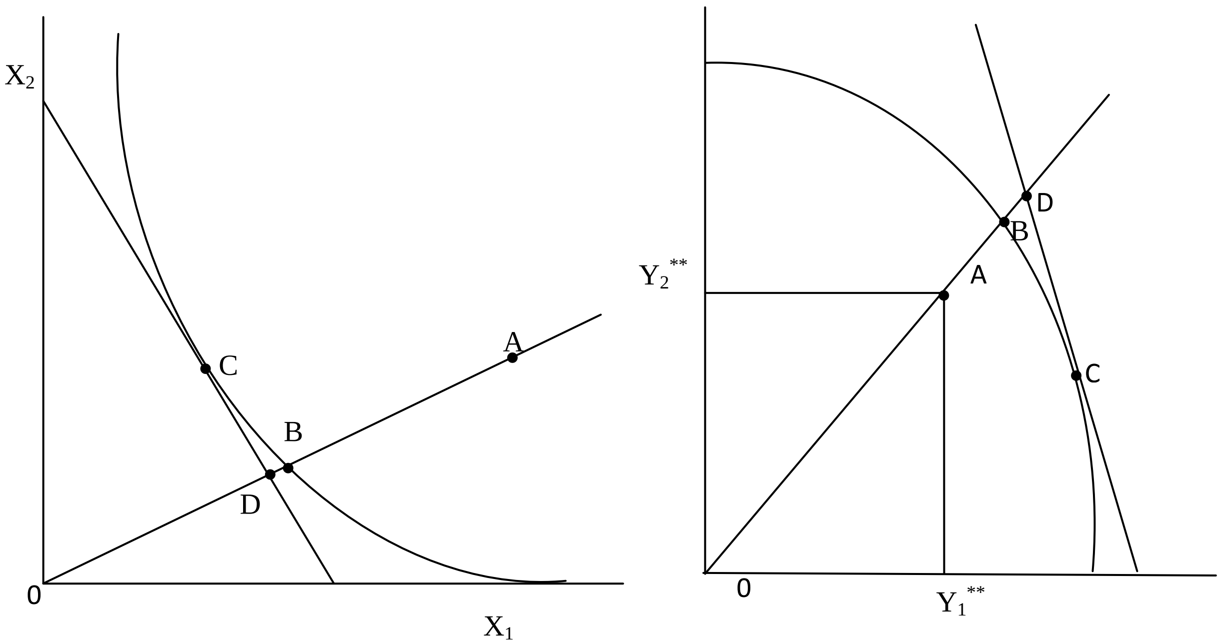
2.1.5 Technical Efficiency Measurement

Production is the process of transforming inputs such as land, labor and capital into output such as goods and services. These production resources can be organized into a farm-firm or producing unit whose ultimate objectives may be profit or revenue maximization, physical output maximization, cost minimization or utility maximization or a combination of the four. In this production possibilities process, the manager or entrepreneur or the firm as the case may be concerned with efficiency in the use of production resources to achieve his goal i.e. the technological and economic efficiency.

Technical efficiency is just one component of overall economic efficiencies. However, in order to be economically efficient, a farm must be technically efficient. Profit maximization requires a farm to produce the maximum output given a level of inputs employed (i.e. be technically efficient), use the right mix of inputs in light of the relative price of each input (i.e. be input allocatively efficient) and produce the right mix of output given the set of price (i.e. be output allocatively efficient) (Kumbhaker and Lovell 2000).

These concepts can be illustrated graphically using a simple example of a set of two inputs (X_1, X_2), and a set of two outputs (Y_1, Y_2) in the production process (Figure 2.2). Efficiency can be considered in terms of the optimal combination of inputs to achieve a given level of output (an input orientation), or the optimal output that could be produced in the given set of inputs (an output orientation). In Figure 2.2(a), the farm is producing a given level of output by using an input combination defined by point A. The same level of output could have been produced by contracting the use of both inputs back to point B, which lies on the iso-quant associated with the minimum level of inputs required to produce such output. The input-oriented level of technical efficiency TE is defined by OB/OA. However, the least cost combination of inputs that produces the same level of output is given by point C where the marginal rate of technical substitution is equal to the input price ratio. To achieve the same level of cost, the input would need to be further contracted to point D. The cost efficiency (CE) is therefore defined by OD/OA. The input allocative efficiency (AE) is given by CE/TE or OD/OB (Kumbhaker and Lovell 2000).

Figure 2.2(b) illustrates the production possibility frontier for a given set of inputs. If the input employed by the farm were used efficiently, the output of the firm can be expanded to point B instead of point A as present. Here, the output oriented measure of technical efficiency can be illustrated by OA/OB. Although point B lying in the production possibility frontier indicates the technical efficiency, higher revenue could be achieved by producing at point C where the marginal rate of transformation is equal to the price ratio. In this case, more of Y_1 should be introduced and less of Y_2 in order to maximize revenue. To achieve the same level of revenue at point C while maintaining the same input and output combination, output of the farm would need to be expanded to point D. Hence, the revenue efficiency (RE) is given by OA/OD. Output allocative efficiency (AE) is given by RE/TE or OB/OD (Kumbhaker and Lovell 2000).



(a) Input oriented efficiency measurement

(b) Output oriented efficiency measurement

Figure 2. 2 Input and output oriented efficiency measurement

2.2 Review of the Studies on Technical Efficiency

Tadesse and Krishnamoorthy (1997) examined the level of technical efficiency in paddy farms of the southern Indian state of Tamil Nadu. The study showed that 90% of the variation in output among paddy (IR-20) farms in the state is due to differences in technical efficiency. Land, animal power and fertilizers had a significant influence on the level of paddy production. The results showed that, with the use of more fertilizers and land, rice production could be increased. The contribution of land in increasing production was more prominent. Farmers were overusing animal power in rice cultivation. The study further indicated that small-sized paddy farms in zone II and medium sized paddy farms in zone III are represented by ecologically based production techniques; thus achieving higher technical efficiency.

Kyi and von Oppen (1999) identified an economic analysis of technical efficiency of rice farmers at delta region in Myanmar. The technical efficiencies of individual observation were estimated by the parametric approach using a stochastic frontier production function for farmers in three different farm sized groups, namely small, medium and large. The empirical results pointed out that urea fertilizer application was the most important explanatory variable in estimating the production frontier.

Mwakalobo (2000) estimated coffee production levels of different farmers and their efficiency in resource use. The results showed that the farmers displayed inefficient use of available resources and were using adequate capital-incentive input levels in order to maximize their output. The result showed that the coffee farmers need to improve their resource use efficiency and productivity. This was shown by using a Cobb-Douglas production function, using Ordinary Least Square techniques.

The technical efficiency and profitability of different farm sizes and different yield levels of rice farmers in Pyinmana Township were estimated by Theingi Myint (2001). The stochastic frontier production function was applied with the FRONTIER 4.1 computer program in the study. The most important constraints to get the highest yield were the high price of fertilizer, the shortage of irrigated water, the limited capital, the poor technical knowledge on plant protection and the availability of information for obtaining the high yield variety seeds. The results stated that small farm size group was the most financially attractive enterprise among the different farm size groups.

Wiboonpogse and Sriboonchitta (2001) analyzed the factor affecting technical efficiency jointly with production frontiers estimated using maximum likelihood method by Frontier 4.1. They stated that the technical inefficiency in jasmine rice and in the non-jasmine rice could be significantly improved. To enhance the yield per rai of jasmine and non-jasmine rice, increased use of chemical fertilizer could be achieved by lowering the fertilizer price or providing more credit. They recommended using more male labor relative to the total labor to reduce the technical inefficiencies for jasmine rice production. However, to reduce the jasmine and non-jasmine rice technical inefficiencies, besides increasing the male labor, technical training to enhance experience in place of age and education must be added for the short-run. They found that the average technical efficiencies (70%) in both kinds of rice imply substantial gaps for the rice yields improvement by increasing their technical efficiencies.

Aye Aye Khin (2002) analyzed the farm-specified technical, allocative and economic efficiencies of the sample sugar farmers in Pyinmana, Tatkone and Yedashe townships. The application of urea fertilizer, the total labor and draft power used by farm from land preparation to transportation and the farmers' experience in sugarcane cultivation were the most important explanatory variables in frontier estimate. All sample farmers were not fully economically efficient in sugarcane production. About 40-70% of the sample farmers achieved moderate economic efficiency in sugarcane production. Therefore, the results pointed out the encouragement for reaching optimal allocation of resources in their farms was necessary to improve their income and welfare.

Rahman (2003) analyzed the profit efficiency by its three components_ technical, allocative and scale efficiency. He provided the direct measure of the efficiency of Bangladesh rice farmers using a stochastic profit frontier and inefficiency effects model. The results indicated that these rice farmers have more experience in growing modern varieties, had better access to input markets which is located in fertile regions and rice farmers who have less off-farm work tend to be more efficient. The results showed that the average profit efficiency score is 0.77 implying that the average farm producing modern rice could increase profits by about 30% by improving their technical, allocative and scale efficiency.

Production efficiency of high-income and low-income pre-monsoon cotton farmers (2002-2003) in Kyaukse and Meikhtila townships was estimated by Tun Win (2004) through technical efficiency measurement to find out factors affecting the production of cotton. Indicating the mean efficiency of pre-monsoon cotton farmers was 0.67, the result implied that in the short run, there was a scope for increasing cotton production by 33% by adopting the technology and techniques used by the best practice of the cotton farms.

The profitability and technical efficiency of sugarcane farmers in private sectors of Katha, Hteegyaint and Thabeikkyin townships was examined by War War Shein (2004). The empirical result stated that Thabeikkyin township was more financially attractive than other townships for both new plant and ratoon. All ratoon farms were more financially attractive than all of new plant farms. The technical efficiency estimates varied from 56% to 100% with a mean value of 77% for new plant farms and from 52% to 94% with an average of 69% for ratoon farms. There was a scope for increasing syrup production by 23% for new plant, and 31% for ratoon farms with the present technology. The study concluded that improvement in technical efficiency was still possible in the private sector. This kind of syrup cottage industry would assist the raw material for syrup-based industry and generate the income of private sugarcane farmers.

Soe Soe Win (2008) focused on technical efficiency of groundnut production in main production areas of Myanmar. The results of the maximum likelihood parameter estimates of the stochastic production frontier from Cobb-Douglas frontier functions for both Mandalay and Magway Divisions indicated that the quality of soil was significant factor that affected the yield per hectare in both regions. The average technical efficiency level was 89% with the range from 45% to 97% in Mandalay and was 73% with the range from 16% to 94% in Magway Division. These results indicated that under existing resources and technology, farmers could increase their technical efficiency or output by 11% for Mandalay and 27% for Magway through the better use of available resources.

May Yee Kay Khine Seine (2008) investigated production efficiency and profitability of soybean farmers in the selected areas. The Cobb-Douglas stochastic production frontier using FRONTIER 4.1 was applied to know the factors affecting the yield of soybean and resource use efficiency in two locations and two income groups. The mean technical efficiency in Kyaukme was 0.49 for all farmers while it was 0.73 for low income group 0.79 for high income group. The mean technical efficiency for all farmers was lower than that of the two income groups. Mean technical efficiencies of all sample farmers were found to be 0.83 in Taunggyi. For low income group, human labor used was negatively significant. For high income group, seed rate and animal labor used showed positive effect while human labor used, bio-super foliar application, farm size and annual income indicated negative impact on yield.

Aung Ko Latt (2010) conducted to estimate the level of technical efficiency of selected rain-fed sesame farmers in Myanmar. To estimate technical efficiency and to know the factors affecting the sesame yield, Cobb-Douglas stochastic frontier production function was applied in a single-stage process using FRONTIER-4.1 computer program. According to the technical efficiency distributions, about 73.04 percent of farmers attained more than 80 percent of technical efficiency level, while none had below 50 percent level of efficiency. In the results of production function, large elasticity of labor with high statistical significance indicated that labor used for performing various farming activities appears to be the most important variable followed by urea and farm yard manure used. Therefore, sesame seems to be labor intensive crop. In the technical inefficiency effects model, only soil conditions as dummy variable was significant at 10 percent level.

CHAPTER III
RESEARCH METHODOLOGY

3.1 Study Area

3.1.1 Description of the Study Area

Magway Region covers 25 townships. Magway Region is surrounded by Mandalay Region and Bago Region as well as Yakhine and Chin regions. Magway Region is situated between North Latitute from 18° 50′ to 22° 47′ and East Longitude from 93° 47′ to 95° 55′, and has an area of 44,820 km^2. Farmland occupies 0.65 million hectares of total arable land (1.01 million hectares) in the Region and the rest lands are paddy land, silt land (Kaing-kyunmyay), hill-side cultivated land (Taungya-myay) and vegetable land. Multiple cropping is practised in the paddy land and farmland.

The study area, Magway Township, is situated on the east bank of the Ayeyarwaddy river. It is bordered by Natmouk Township on the east, Minbu, Sagu and Min Hla Townships on the west, Taungdwingyi and Sinpaungwe Townships on the south, and Yenanchaung Township on the north. Magway Township is made up of 15 quarters, 61 village tracts and 216 villages as mentioned in Appendix 1. Magway Township possesses tropical climatic condition and produces a large quantity of groundnut and sesame for edible oil, it is also known as the oil pot of Myanmar.

3.1.2 Climate

There are three seasons; namely the hot season, rainy season and winter season. Average temperature of the central region are between 37° C and 40° C in summer, especially April which is the hottest month. In winter, the average temperature is 21° C and the lowest temperature is 18° C. The range of the total rainfall of the central region is from 812.8 mm to 863.6 mm. The average relative humidity is about 72.2 % in Magway Region.

Magway Township is situated 56.66 meter above sea level (maximum sea level is 250 meter and minimum sea level is 50 meter. The average monthly temperature was from a minimum of 10.4° C (in January) to a maximum of 43.5° C (in April) (Figure 3.1). A maximum precipitation which was 210 mm was found in October and no precipitation was found in March (Figure 3.2).

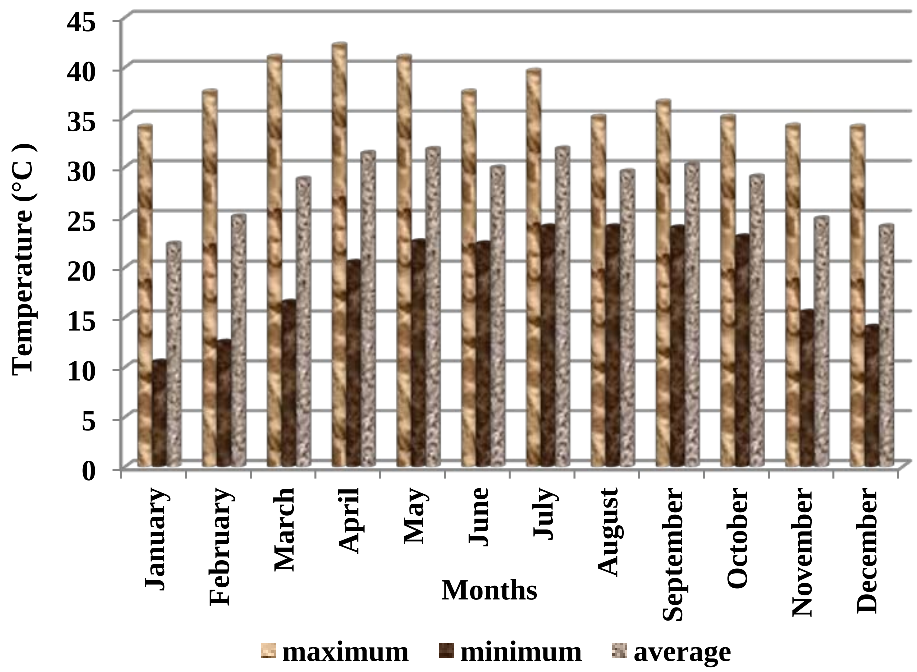


Figure 3. 1 Temperature (° C) in Magway Township (2011)

Source: DOA, Township Office, Magway (2011)

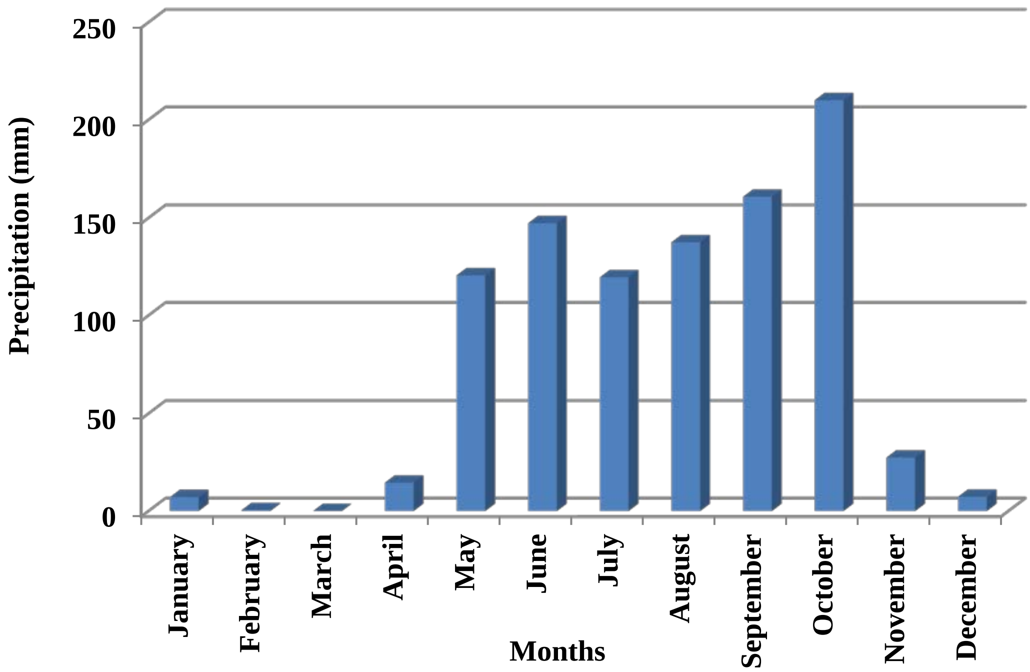


Figure 3.2 Precipitation (mm) in Magway Township, five years average value (2007-2011)

Source: DOA, Township Office, Magway (2011)

3.1.3 Sown Area and Crops Produced

Magway Township occupied a land area of about 176 thousand hectares in which the cultivable area covered 81.41 thousand hectares (46.08%), wild land covered 0.80 thousand hectares (0.45%), reserved and other forests covered 2.34 thousand hectares (1.32%) and others occupied 92.15 thousand hectares (52.15%). Total cultivable area was divided into 1.71 thousand hectares of “Le” land (2.11% in total net sown area), 77.61 thousand hectares of “Ya” land (95.20% in total net sown area), 2.09 thousand hectares of Kai/Kyun (2.55% in total net sown area), 0.002 thousand hectares of orchard (0.12% in total net sown area) (Table 3.1).

“Ya” land is mainly grown for sesame in Magway Township. According to FAO (2007) report, from a practical perspective, “Ya” land is divided into three categories of soil in the lowland which has specific cropping patterns as follows,

- Light texture white soil: mostly one crop per year; monsoon or rainy sesame. An estimated 30 percent can be cultivated with a second crop, generally green gram or black gram.
- Medium texture yellow/red soil: two crops a year; generally monsoon sesame followed by groundnut; or groundnut followed by black gram or sesame. Cool season sesame is cultivated only on 13 percent of the “Ya” land.
- Heavier texture darker/black soil: similar cropping pattern as medium texture soil, but darker soils are more fertile and yield generally higher.

The land type in the study area is nearly similar to first and second categories. Associated with the uneven distribution of rainfall, yield of cultivated crops may also vary on different soil conditions.

Among the total area of cultivable land, sesame growing area was 76 thousand hectares (41.95%). Rain-fed sesame occupied 74.18 thousand hectares (97.29 %) of the total annual sesame producing area, winter sesame 1.96 thousand hectares (2.58%) and summer sesame 0.09 thousand hectares (0.13%). Pulses sown area is 66.91 thousand hectares (36.82%), groundnut 18.64 thousand hectares (10.26%), cotton 9.67 thousand hectares (5.32%), sunflower 6.68 thousand hectares (3.67%) and paddy 3.59 thousand hectares (1.98%) in Table 3.2. Among these crops, rain-fed sesame is the dominant crop for rainy or monsoon season at the township level.

Table 3.1 Land utilization in Magway Township (2010-2011)

S.N	Type of land	Area ('000 hectare)	Percent in total sown area
(1)	Net sown	81.41	46.08
	(a)"Le" land	1.71	(2.11)
	(b)"Ya" land	77.61	(95.20)
	(c) Kai/Kyun	2.09	(2.57)
	(d) Orchard	0.002	(0.12)
(2)	Wild land	0.80	0.45
(3)	Reserved and other forest	2.34	1.32
(4)	Others	92.15	52.15
Total		**176.70**	**100**

Note: Figures in the parenthesis are percentage in total net sown area.

Source: DOA, Township Office, Magway (2011)

Table 3 2 Cultivation of sesame and other crops in Magway Township

Crops	Area ('000 hectare)	Percent
Sesame	76.24	41.95
- Monsoon sesame (Rain-fed sesame)	74.18	(97.29)
- Post-monsoon sesame (Winter sesame)	1.97	(2.58)
-Pre-monsoon sesame (Summer sesame)	0.09	(0.13)
Pulses	66.91	36.82
Groundnut	18.64	10.26
Cotton	9.67	5.32
Sun flower	6.68	3.67
Paddy	3.59	1.98
Total crop area	**181.73**	**100**

Note: Figures in the parenthesis are percentage in total sesame sown area.

Source: DOA, Township Office, Magway (2011)

3.2 Data Collection and Sampling Method

Cross-sectional data were collected from Magway Township in Magway Region. The survey was done in December 2011 and January 2012 to study the technical efficiency of sesame production in the selected areas. A comprehensive review was executed from Department of Agriculture (DOA). The household level survey in Magway Township was carried out in four villages (Table 3.3). A total of 130 sample farmers was personally interviewed with well-structured standardized questionnaire to obtain the primary data using random sampling method.

The primary data included-

(1) the social characteristics of the sample farmers such as age, education level, household's experience in sesame production, family size, family labor and numbers of visit by extension agents;

(2) farming practices such as land owned, sesame area, methods of sowing, availability of water, use of varieties, seed rate per acre, use of fertilizer, pesticide and manure, labor availability and yield obtained;

(3) the constraints of sesame production;

(4) value of sesame production of sample farmers.

The secondary data on sesame production such as yield and sown area and input was obtained from Settlement and Land Records Department, Department of Agricultural Planning (DAP), Department of Agriculture (DOA) and other relevant sources.

Table 3.3 Information based on the farm household survey in Magway Township (2011-2012)

Village Name	Name of Village Tract	Population	Total no. of HH	No. of farm HH	No. of non-farm HH
Magyigan	Magyigan	2,850	610	200	410
Sartaigan	Sartaigan	3,051	696	171	525
Thapyaysan	Thapyaysan	1,700	321	220	101
Shwe Kyin	Zeekyun	1,244	104	100	4

Note: HH = Household

3.3 Data Analysis Methods

3.3.1 Descriptive Analysis

Descriptive analysis was applied to describe and compare the socio-economic conditions, input use, yield, existing farming practices and income of sesame farmers etc..

3.3.2 The Total Households Income Function

The following model was used to examine the determinant factors of total household's income:

$$Ln\ IC_i = \beta_0 + \beta_1 LnX_{1i} + \beta_2\ LnX_{2i} + \beta_3\ LnX_{3i} + \beta_4\ LnX_{4i} + \beta_5\ LnX_{5i} + \beta_6\ LnX_{6i} + \mu_i$$

Where,

IC_i = The total household income per year for i^{th} households

X_{1i} = Crop income

X_{2i} = Livestock income

X_{3i} = Selling income

X_{4i} = Government or company staff income

X_{5i} = Migration income

X_{6i} = Other income

μ_i = Disturbance terms

3.3.3 Crop Income Function

The following equation was used to examine the influencing factors of total crop income:

$$Ln\ ICC_i = \beta_0 + \beta_1 LnX_{1i} + \beta_2\ LnX_{2i} + \beta_3\ LnX_{3i} + \beta_4\ LnX_{4i} + \beta_5\ LnX_{5i} + \mu_i$$

Where,

ICC_i = The total crop income per year for i^{th} households

X_{1i} = Rain-fed groundnut income

X_{2i} = Rain-fed sesame income

X_{3i} = Winter groundnut income

X_{4i} = Green gram income

X_{5i} = Pigeon pea income

μ_i = Disturbance terms

3.3.4 Economic Analysis

The concept of enterprise budget (Olson 2009) was used to evaluate the profitability of sesame production. In this analysis, variable costs were taken into account;

(1) Material input cost,
(2) Hired labor cost,
(3) Family labor cost, and
(4) Interest on cash cost.

The interest was normally charged on cash expense for early in the growing season. The counted interest rate was 1.5 % per month for six months.

The first measurement was the difference between the total gross benefits or total returns and total variable cash costs, excluding opportunity costs. This value was referred to as “return above variable cash cost”.

The second measurement was the deduction of the opportunity cost and total variable cash costs from gross benefit. This return was referred to as “return above variable costs” or “gross margin”.

The “return per unit of capital invested” could be calculated by gross benefits per total variable costs. The “return per unit of cash cost” could be calculated by gross benefits per total cash costs.

These measurements could be expressed with equations as:

Measurement (1)

Return above variable cash cost = Total gross benefit – total variable cash cost

Measurement (2)

Return above variable cost = Total gross benefit – total variable cost
(Gross margin)

Measurement (3)

$$\text{Return per unit of capital invested} = \frac{\text{Total gross benefit}}{\text{Total variable cost}}$$

Measurement (4)

$$\text{Return per unit cash cost} = \frac{\text{Total gross benefit}}{\text{Total cash cost}}$$

3.3.5 Empirical Model of Stochastic Frontier

In order to estimate the Cobb-Douglas Stochastic frontier production function, the software_ FRONTIER 4.1 (Aigner *et al.* 1977) was used. The maximum likelihood estimate of the parameters of the frontier model was estimated. The stochastic frontier model for sesame farmers in the study areas was explained by using the equation (1) and (2).

$$LnY_i = \beta_0 + \beta_1 LnX_{1i} + \beta_2 LnX_{2i} + \beta_3 LnX_{3i} + \beta_4 LnX_{4i} + \beta_5 LnX_{5i} + e_i \quad \text{....................(1)}$$

Where:

Ln = Natural logarithm

i = i th farm in the sample

Y = Yield of sesame (kg/ha)

X_{1i} = Seed rate used (kg/ha)

X_{2i} = Manure (FYM) used (ton/ha)

X_{3i} = Urea fertilizer used (kg/ha)

X_{4i} = Human labor used (man day/ha)

X_{5i} = Animal labor used (animal day/ha)

β_0 = Constant

β_i = Estimated coefficients, i = 1,2,3, … etc.

e_i = ν_i - μ_i ($\mu_i \geq 0$)

ν_i = Independent and identically distributed random errors, having N (0, σ^2) independent of the μ_i

μ_i = Technical inefficiency effects which are assumed to be non-negative random variable independently and identically distributed such that μ_i is defined by the truncation at zero of the N (0, σ^2)

The technical efficiency of production for the ith farm is defined as the ratio of observed output to the corresponding maximum feasible output associated with no technical inefficiency as expressed in previous section and is described by the following equation:

$$TE_i = \exp(-U_i) = \frac{\text{Observed output}}{\text{Maximum feasible output}}$$

After obtaining farm specific technical efficiency, the sources of the inefficiency were identified by making appropriate analysis. Moreover, investigating the sources of technical inefficiency were particular interests of researchers who analyzed the technical efficiency of crop production.

The literature of the previous studies indicates that socio-economic and demographic characteristics of farmers such as age and education of farmers, farming experiences, credit and extension assets, etc. and farm characteristics such as land size and soil fertility, etc. would also determine the technical efficiency or inefficiency.

$\boldsymbol{\mu_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3}$ ....(2)

μ_i = Technical inefficiency effect predicted by the model itself

δ_0 = Constant

δ_i = Parameters to be estimated, i = 1,2,3

Z_1 = Farm size (hectare)

Z_2 = Education level of farmer (schooling year)

Z_3 = Household head's experience in sesame farming (year)

In this study, following Battese and Coelli (1995), the parameters of the stochastic production frontier and inefficiency effect models are jointly estimated in a single stage by using the maximum likelihood estimation method. They criticized about a two-stage analysis_ the first stage involves the specification and estimation of the stochastic frontier production function and the prediction of the technical inefficiency effects under the assumption that these effects are identically distributed; the second stage involves the specification of a regression model for the predicted technical inefficiency effects, which contradicts the assumption of identically distributed inefficiency effects in the stochastic frontier. Coelli and Battese (1996) and Rahman (2008) also used the single-stage approach in their stochastic frontier analysis. Some of the main researchers who have utilized the stochastic frontier analysis are: Aigner *et al.* (1977), Battese and Coelli (1995), Coelli and Battese (1996), Battese *et al.*, (1996) and Bravo-Ureta and Pinheiro, (1997). Several studies have been carried out on technical efficiency analysis in global, especially in developing countries, as well as in Myanmar.

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Social Characteristics of Sample Farm Households in Magway Township

4.1.1 Farm Size Distribution of Sampled Farm Households

Farm households were classified into three groups according to their land holding sizes as shown in Table 4.1. There were about 25.38% of farmers who own small farm within the range of 0.40 to 2.02 hectares. 32.31% of farmers who own medium farm within the range of 2.43 to 4.05 hectares and 42.31% of farmers who own large farm within the range of 4.45 to 20.23 hectares. The average farm size of small farm household was 1.48 hectares, medium was 3.47 hectares and large was 8.79 hectares respectively. The average farm size for total farm household was 5.22 hectares. The F-test showed that there was significant difference in land holding size among small, medium and large farm households.

4.1.2 Gender Status of Household Heads and Socio-demographic Condition for Different Farm Households

The gender status of the household heads and social characteristics of the sample farm households were presented in Table 4.2 and Table 4.3. The number and percentage of male household heads and female household heads of total sample farmers were 108 (83.10%) and 22 (16.90%). About 69.70% of small, 81.0% of medium and 92.70% of large farm household heads were males. The rest of 30.30% of small, 19.00% of medium and 7.31% of large farm households were females. Pearson Chi-square test shows the gender of household heads was significant difference among three different farm households.

Table 4. 1Categories of sample farm households based on their own farm size

H/H groups	Number	Average farm size (ha)	Minimum farm size (ha)	Maximum farm size (ha)
Small farm households (0.00-2.02 ha)	33 (25.4)	1.48	0.4	2.02
Medium farm households (2.03-4.05 ha)	42 (32.3)	3.47	2.43	4.05
Large farm households (more than 4.05 ha)	55 (42.3)	8.79	4.45	20.23
F-test		F = 107.801***		
Total	**130**	**5.22**	**0.4**	**20.23**

Note: Figures in the parentheses represent percentage.
*** is significant at 1% level.

Table 4.2 Gender status of sample farm households

(Number)

Gender of household head	Small farm households (n=33)	Medium farm households (n=42)	Large farm households (n=55)	Total farm households (n=130)
Male household head	23 (69.70)	34 (81.0)	51 (92.70)	108 (83.10)
Pearson Chi-square		P = 0.018**		
Female household head	10 (30.30)	8 (19.00)	4 (7.31)	22 (16.90)
Pearson Chi-square		P = 0.018**		

Note: Figures in the parentheses represent percentage.
** is significant at 5% level.

In Table 4.3, the average age of the all sample farm household heads was 52.05 years. The eldest of sample farmers was 53.24 years in age and was found in large farm households. The average age of the small farm households was 50 years and it was the youngest among the sample farmers. The average age of the medium farm household heads had 52.12 years. The average age of the sample farmers was not significantly different in the study area.

The average schooling years of household heads were 5.33 years in small households, 5.12 years in medium households and 8.47 years in large households respectively. The average schooling years of household heads for all farm households were 6.59 years. The F-test showed that the average schooling years of household heads of sample farm households were significantly different. The household heads' education level were divided into monastery level, primary level, secondary level, high school level, university level. The highest education level of small farm household head was high school level. Only one medium farm households' head with higher education (University) level was found in the study area. In large farm households, 15 (27.27%) of household heads with university level were found. Therefore, large farm households' heads were more educated than the other two.

The large farm households' heads had 27.05-year farm experience on average. Over 26-year farming experience was found in medium farm households' heads, while small farm households' heads had less experience in farming of 17.63 years on average. There was significantly difference in farm experience of sample farmers among three different holding land sizes.

Table 4.3 Socio-demographic characteristics of sample farm households

Items	Unit	Small farm households (n=33)	Medium farm households (n=42)	Large farm households (n=55)	Total farm households (n=130)
Average head's age	Year	50	52.12	53.24	52.05
F-test			F = 0.660^{ns}		
Average head's schooling year	Year	5.33	5.12	8.47	6.59
F-test			F = 13.94***		
Head's education level					
Monastery	Number	3	10	9	22
Primary	Number	15	15	0	30
Secondary	Number	14	14	17	45
High school	Number	1	2	14	16
University level	Number	0	1	15	16
F-test			F = 18.172***		
Average head's farm experience	Year	17.63	26.93	27.05	24.62
F-test			F = 5.37***		

Note: *** is significant level at 1% level and ns = not significant.

4.1.3 Family Size and Labor of Sample Farm Households

Family size and labor availability of sample farm households were presented in Table 4.4. The average family members were 4.06, 4.38 and 4.78 of the small, medium and large farm households. The average family members were 4.47 in total farm households. Family size was not significantly different among three farm households. Active labor forces were 2.52, 2.55 and 2.69 members in small, medium and large farm households, respectively. There was no significant difference in active labor among sample farm households. Among the active labor, the larger number of family labor in agriculture was 2.07 members and was found in medium farm households. The lower number of family labor in agriculture was 1.93 and was observed in large farm households. There was no significant difference in agriculture labor of family members in sample farm households.

4.1.4 Comparison of Sample Households in the Ownership of Farming Assets

The sample farm households in the ownership of the farming assets were presented in Table 4.5. The large farm households possessed more plough, harrow and oxen than small and medium ones. About 98.18%, 98.18%, 98.18% and 54.55% of large farm households had plough, harrow, cattle and cow, respectively. About 80.95%, 78.57%, 71.43% and 50.00% of medium farm households possessed plough, harrow, cattle and cows, respectively. About (54.55%) had plough and harrow, and 48.48% and 54.55% of small farm households had cattle and cows, respectively. Small and medium farmers did not possess any tractor. However, only 12.73% of large farmers possessed tractors. About 33.33% of small farm households, 59.52% of medium farm households and 94.55% of large farm households possessed motor bike used in farming and for other purposes. In the ownership of farming assets, there was significant difference in all items except ownership of cow in the sample farm households.

Table 4.4 Family size and labor of sample farm households

(Number)

Indicator	Small farm households (n=33)	Medium farm households (n=42)	Large farm households (n=55)	Total farm households (n=130)
Family size	4.06	4.38	4.78	4.47
F-test		$F = 2.904^{ns}$		
Active labor	2.52	2.55	2.69	2.6
F-test		$F = 0.278^{ns}$		
Agricultural labor	2.03	2.07	1.93	2
F-test		$F = 0.237^{ns}$		

Note: ns = not significant

Active labor means the persons who work at any job.

Table 4.5 Number and percentage of sample farm households who owned farming assets

Assets	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
Plough	18 (54.55)	34 (80.95)	54 (98.18)	106 (81.54)
Pearson Chi-square		P = 0.016**		
Harrow	18 (54.55)	33 (78.57)	54 (98.18)	105 (80.77)
Pearson Chi-square		P = 0.011**		
Cattle	16 (48.48)	30 (71.43)	54 (98.18)	100 (76.92)
Pearson Chi-square		P = 0.000***		
Cow	18 (54.55)	21 (50.00)	30 (54.55)	69 (53.08)
Pearson Chi-square		P = 0.889ns		
Bullock cart	19 (57.58)	29 (69.05)	54 (98.18)	102 (78.46)
Pearson Chi-square		P = 0.000***		
Sprayer	12 (36.36)	29 (69.05)	55 (100)	96 (73.85)
Pearson Chi-square		P = 0.000***		
Animal yard	23 (69.70)	35 (83.33)	55 (100)	113 (86.92)
Pearson Chi-square		P = 0.001***		
Tractor	0 (0)	0 (0)	7 (12.73)	7 (5.38)
Pearson Chi-square		P = 0.006**		
Motor bike	11 (33.33)	25 (59.52)	52 (94.55)	88 (67.69)
Pearson Chi-square		P = 0.000***		

Note: Figures in the parentheses represent percentage.

** and *** are significant at 5% and 1% level respectively, and ns= not significant.

4.1.5 Percentage Share of Total Household Income of Sample Farm Households

The household income of survey area was composed of income from three different sources. They generated income through farming activities including crop production and livestock production. Additional income came from non-farm activities such as selling goods, government or company staff, migration other countries and drivers. The average income sources of the sampled farmers were presented in Appendix 2. The percentage of the distribution of the household income for small, medium and large farm households was presented in Figure 4.1.

In small farm households, about 53.50% of the family income was crop income which was the main source of income. About 17.90% of the family income was second source of income for which income was generated from government and company staff. The third income was income from selling goods which contributed about 17.37% of the family income followed by other income from livestock and migration. In medium farm households, the crop income was the main source of income, sharing about 65.88% of the family income. Income from migration was about 12.35% of the family income and the third source was income from selling goods followed by income from other sources, government or company staff and livestock. In large farm households, the main source of income was crop income about 82.43% of family income and the second was income from selling goods (5.45%) of the family income followed by income from migration, other sources, government or company staff and livestock. Percentage share of crop income was the highest among the sample farm households.

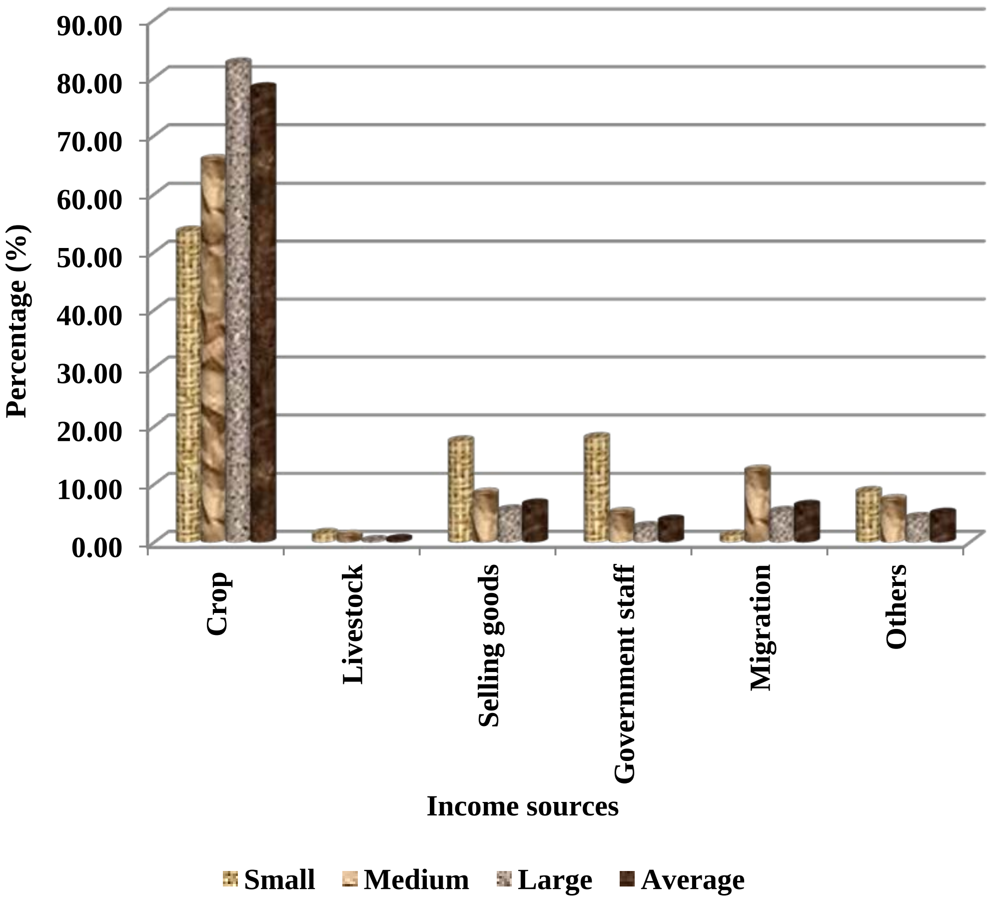


Figure 4.1 Percent of distribution income sources among sample farm households

4.1.6 Factors Influencing the Total Households Income of the Sample Farmers

Table 4.6 showed the estimation result of the total households' income for small, medium and large farm households, respectively. Total households' income was estimated by using natural logarithm of 6 variables: crop income, livestock income, income from selling goods, income from government or company staff, income from migration and other income.

In the sample farm households, total household income was positively and significantly influenced by crop income, income from selling goods and government or company staff at 1% level. Other things being equal, 1% increase in income from crop, selling goods and government staff may attribute to improve family income by about 0.76%, 0.25% and 0.41% respectively in small farm households. Other things being equal, 1% increase in crop income, income from selling goods and government or company staff may increase total households' income in medium farm size by 0.87%, 0.07%, and 0.06%, respectively. Other things being equal, if crop income, income from selling goods and government or company staff were increased by 1%, total households' income was increased by 0.84%, 0.02% and 0.03%, respectively in large farm size. Livestock income was not significant in all sample farm households. Income from migration significantly influenced on total household income at 1% level in medium and at 5% level in large farm households, and not significantly influenced in small farm households. Income from others was not significant in small farm households but significant influenced in medium and large farm households at 1% level. As in all farm households, the total household income were significantly influenced by crop income, selling goods income and government or company staff income but livestock income, migration income and other income were not significant at both 1% and 5% level.

Table 4.6 Factors influencing on total household incomes by different income sources among the sample farm households

Variables	Small farm Households		Medium farm households		Large farm households		All farm households	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Intercept	2.39**	2.64	1.81***	4.70	2.39***	4.56	3.29***	7.00
LN crop income	0.76***	9.06	0.87***	30.54	0.84***	23.27	0.75***	21.32
LN livestock income	0.05^{ns}	0.48	0.01^{ns}	0.89	0.00^{ns}	-0.23	0.01^{ns}	0.29
LN selling goods income	0.25***	2.81	0.07***	11.03	0.02***	4.38	0.08***	3.51
LN government staff	0.41***	3.98	0.06***	6.57	0.03***	4.08	0.12***	4.23
LN migration income	0.07^{ns}	0.29	0.13***	12.64	0.03**	2.16	0.04^{ns}	0.76
LN others	0.04^{ns}	0.29	0.07***	9.70	0.03***	3.19	0.03^{ns}	0.97
Multiple R	0.90		0.99		0.97		0.90	
R Square	0.81		0.98		0.94		0.81	
Adjusted R Square	0.77		0.97		0.94		0.80	
Standard Error	2.30		0.17		0.25		1.34	
Observations	33.00		42.00		55.00		130.00	

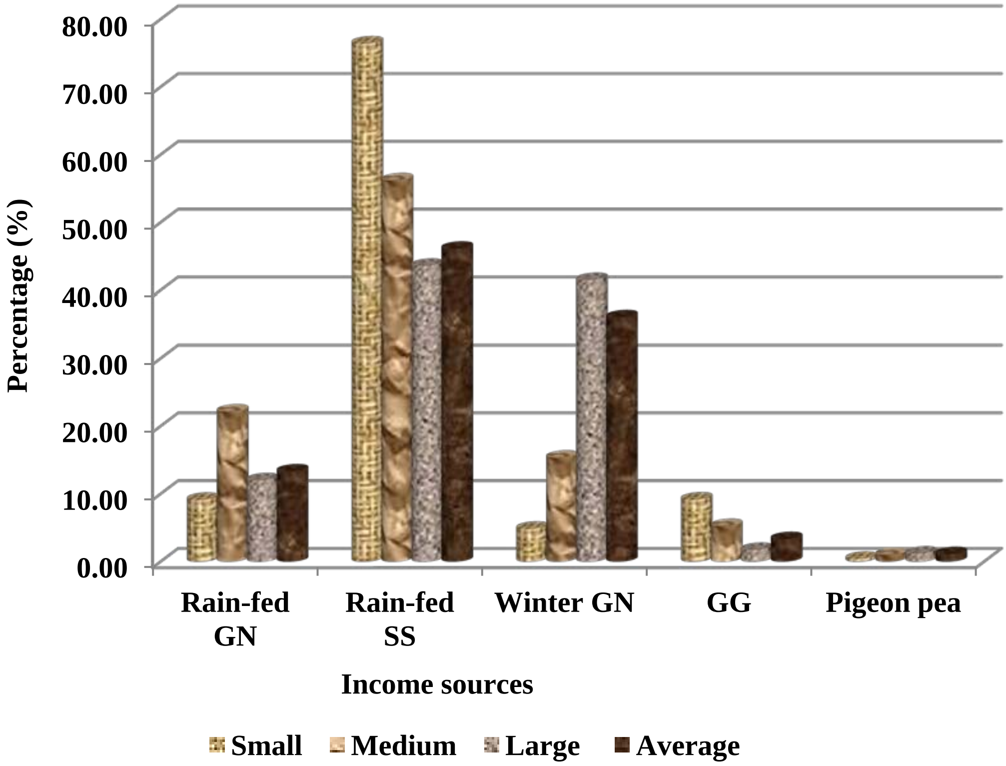
Note: LN = Natural Logarithm

** and *** are significant different at 5% level and 1% level, respectively and ns = not significant

4.1.7 Percentage Share of Total Crop Income of Sample Farm Households

Crop income mainly included the incomes from rain-fed groundnut, rain-fed sesame, winter groundnut, green gram and pigeon pea. The average crop income was presented in Appendix 3. Figure 4.2 represented the percentage of the distribution of different crop income for small, medium and large farm households.

In small farm households, rain-fed sesame income was the main source of crop income_ about 76.42% of the total crop income followed by green gram income (9.17%), rain-fed groundnut income (9.13%), winter groundnut income (4.85%) and pigeon pea income (0.42%) of the total crop income. In medium farm households, the rain-fed sesame income was the main source of crop income about 56.22% of the total crop income followed by rain-fed groundnut income (22.16%), winter groundnut income (15.35%), green gram income (5.25%) and pigeon pea income (1.02%) of the total crop income. In large farm households, the main source of crop income was income from rain-fed sesame crop (43.58%) of total crop income followed by winter groundnut income (41.49%), rain-fed groundnut income (12.01%), green gram income (1.73%), and pigeon pea income (1.18%) of total crop income. Rain-fed sesame income was the main source and rain-fed and winter groundnut were the second source of crop income among the sample farm households. Therefore, rain-fed sesame is the important and major crop in the study area.



Note: GN = Groundnut, SS = Sesame, GG = Green gram

Figure 4.2 Percent distribution of crop income among the sample farm households

4.1.8 Factors Influencing the Total Crop Income of the Sampled Farmers

Table 4.7 indicated the estimation result of the total crop income for small, medium and large farm households. Total crop income was estimated by using natural logarithm of five variables: rain-fed groundnut income, rain-fed sesame income, winter groundnut income, green gram income and pigeon pea income.

In sample farm households, total crop income was positively and significantly influenced by rain-fed groundnut income, rain-fed sesame income and green gram income at 1% level. Other things being equal, 1% increase in rain-fed groundnut income and rain-fed sesame income can increase the total crop income by 0.52% and 0.70% respectively in small farm households. Other things being equal, 1% increase in rain-fed groundnut income and rain-fed sesame income can increase the total crop income by 0.06% and 0.09% respectively in medium farm households. Other things being equal, 1% increase in rain-fed groundnut income and rain-fed sesame income can increase the total crop income by 0.03% and 0.78% respectively in large farm households. Winter groundnut income in medium and large farm size was highly significant at 1% level but not significant in small farm size. Total crop income was significantly influenced by green gram income in small farm size but not significant in medium and large farm size.

Table 4.7 Factors influencing on crop incomes by different crops among the sample farm households

Variables	Small farm Households (n =33)		Medium farm households (n = 42)		Large farm households (n = 55)		All farm Households (n = 130)	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Intercept	2.37***	2.74	12.00***	51.30	3.00***	3.66	6.74***	13.08
LN RGN	0.52***	3.45	0.06***	4.14	0.03***	3.27	0.11***	3.32
LN RSS	0.70***	8.67	0.09***	5.29	0.78***	13.20	0.44***	10.30
LN WGN	-0.20 ns	-1.25	0.06***	3.89	0.04***	3.91	0.06 ns	1.67
LN GG	0.38***	3.75	0.01 ns	0.28	0.01 ns	1.35	0.07***	2.00
LN pigeon pea	0.15 ns	0.58	-0.04 ns	-1.52	0.01 ns	1.05	0.02 ns	0.46
Multiple R	0.89		0.83		0.93		0.78	
R Square	0.79		0.70		0.87		0.61	
Adjusted R Square	0.75		0.66		0.85		0.59	
Standard Error	2.60		0.55		0.38		2.18	
Observations	33.00		42.00		55.00		130.00	

Note: LN = natural logarithm, RGN = Rain-fed Groundnut, RSS = Rain-fed Sesame, WGN = Winter Groundnut, GG = Green Gram

** and *** are significant different at 5% level and 1% level, respectively and ns = not significant.

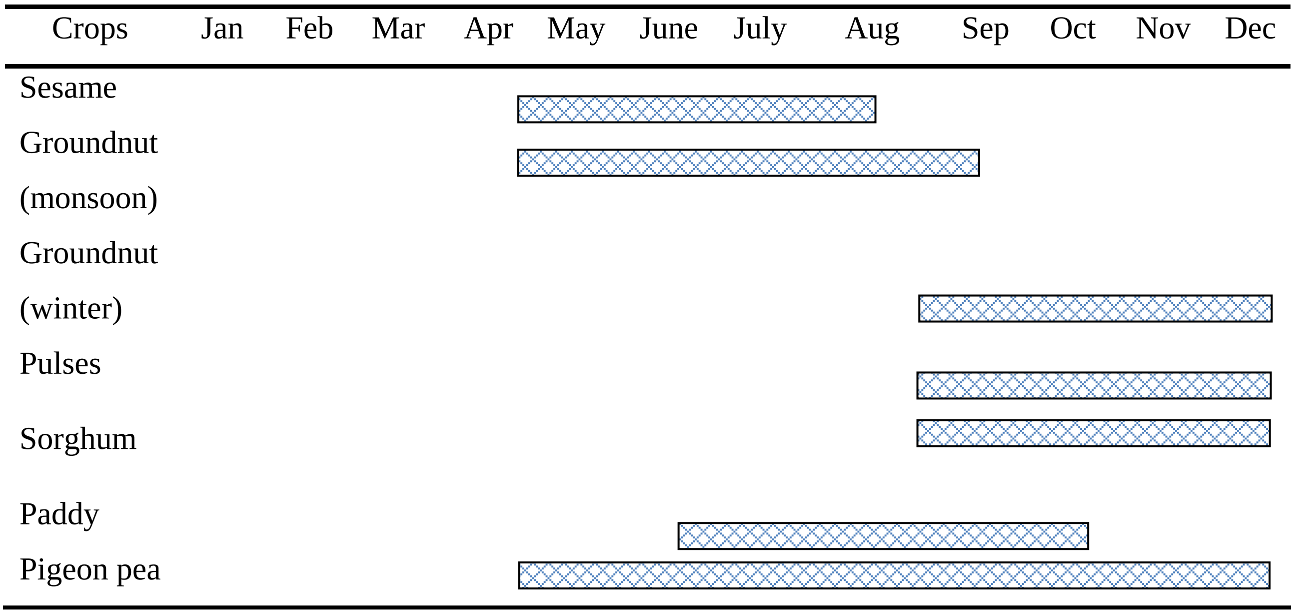
4.2 Cropping Patterns and Inputs Used in Rain-fed Sesame Production in the Study Area

4.2.1 Crop Calendar and Cropping Patterns

In Magway Township, sesame and groundnut are grown as the first crops in monsoon season. Farmers prepared their land and grew sesame or groundnut in the end of April and harvested in the end of August for sesame and in the end of September for the groundnut as shown in Table 4.8. After harvesting sesame and groundnut, most of the farmers grew pulses including green gram and cow pea, sorghum and some of the farmers grew winter season groundnut. Winter season crops are harvested in the end of December.

Sesame is a dominant crop in the cropping systems in Magway Township. The cropping patterns mostly grown in Magway Township were presented in Table 4.9. Among fourteen cropping patterns, only one farmer (3.03%) of small farm households grew only rain-fed sesame and another one (3.03%) of small farm households grew rain-fed sesame followed by sorghum. Rain-fed sesame followed by pulses cropping pattern was grown by 33.33% of small farm households and 9.52% of medium farm households. Also in rain-fed sesame followed by pulses and sorghum, there were two farmers (6.06%) of small households and three farmers (7.14%) of medium households. There were 10 total farmers who grew rain-fed sesame followed by winter groundnut, pulses and sorghum. Only two large farm households grew rain-fed sesame and rain-fed groundnut followed by pulses. One farmer (3.03%) of small households and two farmers (4.76%) of medium households grew rain-fed sesame intercropped with pigeon pea and groundnut followed by pulses. Paddy followed by fallow cropping patterm was grown in medium farm households and large farm households who possessed low land ("Le" land). Among fourteen cropping patterns, farmers grew mostly rain-fed sesame and rain-fed groundnut followed by winter groundnut, pulses and sorghum. But only one person (3.03%) of small farm households grew this pattern, and 21.43% of medium and 47.27% of large farm households grew this pattern. Pearson Chi-square showed that there was significant difference in rain-fed sesame followed by pulses, rain-fed sesame followed by winter groundnut and pulses, rain-fed sesame and rain-fed groundnut followed by winter groundnut and pulses, and rain-fed sesame and rain-fed groundnut followed by winter groundnut and pulses and sorghum cropping patterns. There was no significant difference in other cropping patterns.

Table 4.8 Crop calendar grown different crops in the study area



Source: DOA, Township Office, Magway (2011)

Table 4.9 Percentage of sample farmers for each cropping pattern in the study area

(Number of farmers)

Cropping pattern	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
RSS	1 (3.03)	0 (0)	0 (0)	1 (0.77)
Pearson Chi-square		P = 0.227^{ns}		
RSS-SG	1 (3.03)	0 (0)	0 (0)	1 (0.77)
Pearson Chi-square		P = 0.227^{ns}		
RSS-PS	11 (33.33)	4 (9.52)	0 (0)	15 (11.54)
Pearson Chi-square		P = 0.000***		
RSS-PS, SG	2 (6.06)	3 (7.14)	0 (0)	5 (3.85)
Pearson Chi-square		P = 0.144^{ns}		
RSS+PP-PS	3 (9.09)	4 (9.25)	0 (0)	7 (5.38)
Pearson Chi-square		P = 0.066^{ns}		
RSS+PP-SG	0 (0)	2 (4.76)	3 (5.45)	5 (5.38)
Pearson Chi-square		P = 0.407^{ns}		
RSS-WGN, PS	11 (33.33)	4 (9.52)	4 (7.27)	19 (14.62)
Pearson Chi-square		P = 0.002***		
RSS-WGN, PS, SG	2 (6.06)	6 (14.29)	2 (3.64)	10 (7.69)
Pearson Chi-square		P = 0.137^{ns}		
RSS, RGN-PS	0 (0)	0 (0)	2 (3.64)	2 (1.54)
Pearson Chi-square		P = 0.250^{ns}		
RSS+PP, RGN-PS	0 (0)	2 (4.76)	3 (5.45)	5 (3.85)
Pearson Chi-square		P = 0.407^{ns}		
RSS+PP, RGN-PS	1 (3.03)	2 (4.76)	0 (0)	3 (2.31)
Pearson Chi-square		P = 0.287^{ns}		
RSS, RGN-WGN, PS	0 (0)	5 (11.90)	14 (25.45)	19 (14.62)
Pearson Chi-square		P = 0.004***		
RSS, RGN-WGN, PS, SG	1 (3.03)	9 (21.43)	26 (47.27)	36 (27.69)
Pearson Chi-square		P = 0.000***		
PD-F	0 (0)	1 (2.38)	1 (1.82)	2 (1.54)
Pearson Chi-square		P = 0.690^{ns}		

Note: Figures in the parentheses represent percentage.

RSS = Rain-fed Sesame, SG = Sorghum, PS = Pulses, WGN = Winter Groundnut,

RGN = Rain-fed Groundnut, PP = pigeon Pea, PD = Paddy, F = fallow

*** is significant at 1% level and ns = not significant

4.2.2 Sesame Seed Variety and Seed Rate Used

Myanmar has many varieties of sesame, the nomenclature varies from region to region, the terms relate to the characteristics of the stems, fruits and color of the seeds. However, the differences of principle lie between the short-duration and long-duration sesame.

In Magway Township, there are three main varieties: white sesame, black sesame and red sesame. Among these three varieties, few farmers grow red sesame. In the study area, black sesame and white sesame are mostly grown. The number and percentage of farm households who grew the different varieties were presented in Table 4.10. Among 130 sample farmers, 16 (48.48%) of small farmers, 27 (64.24%) of medium farmers and 20 (36.36%) of large farmers grew black sesame. Therefore, there was 63 farmers who grew black sesame. White sesame was grown by 17 (51.52%) of small farmers, 15 (35.71%) of medium farmers and 35 (63.64%) of large farmers. The total white sesame farmers was 67 farmers. Pearson Chi-square showed that there was significant different in both black sesame and white sesame used by the different farm households.

Varieties used by the sampled farmers in the study area were shown in Table 4.11. Samon (local variety) and Theikpan (improved variety) are black sesame. Ba Pan, Chonegyaw, Phyuma and Shwetosote were local varieties of white sesame used in the study area. About 61 farmers (46.9%) of the total farmers grew black sesame (Samon). Only two large farmers grew Theikpan. In white varieties, Ba Pan was the most grown variety followed by Phyuma, Chonegyaw and Shwetasote. There was not significantly different in varieties used among three different farm households except in Samon.

Table 4.10 Percentage of farmers growing different varieties among the different groups of sample farmers

(Number of farmers)

Item	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
Black sesame	16 (48.48)	27 (64.24)	20 (36.36)	63 (48.46)
Pearson Chi-square		P = 0.024**		
White sesame	17 (51.52)	15 (35.71)	35 (63.64)	67 (51.54)
Pearson Chi-square		P = 0.024**		

Note: Figures in the parentheses represent percentage.

** is significant at 5% level.

Table 4.11 Percentage of sample farmers' varieties used by different groups of sample farmers

(Number of farmers)

Variety	Color	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
Ba Pan (Local variety)	White	3 (9.1)	8 (19.0)	15 (27.3)	26 (20.0)
Pearson Chi-square			$P = 0.117^{ns}$		
Chonegyaw (Local variety)	White	3 (9.1)	1 (2.4)	9 (16.4)	13 (10.0)
Pearson Chi-square			$P = 0.074^{ns}$		
Phyuma (Local variety)	White	9 (27.3)	5 (11.9)	8 (14.5)	22 (16.9)
Pearson Chi-square			$P = 0.175^{ns}$		
Shwetasote (Local variety)	White	2 (6.1)	1 (2.4)	3 (5.5)	6 (4.6)
Pearson Chi-square			$P = 0.697^{ns}$		
Samon (Local variety)	Black	16 (48.5)	27 (64.3)	18 (32.7)	61 (46.9)
Pearson Chi-square			$P = 0.011^{**}$		
Theikpan (Improved variety)	Black	0 (0.0)	0 (0.0)	2 (3.6)	2 (1.5)
Pearson Chi-square			$P = 0.250^{ns}$		

Note: Figures in the parentheses represent percentage.

** is significant at 5% level and ns = not significant.

Table 4.12 Amount of sesame seed used by different groups of sample farmers

Seed usage (kg/ha)

Indicator	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
Mean	17.19	16.75	17.60	17.22
Minimum	11.35	11.35	7.56	7.56
Maximum	30.26	22.69	30.26	30.26
F-test		$F = 0.453^{ns}$		

Note: ns = not significant

Table 4.12 showed the amount of sesame seed used in different groups of sample farmers. Average amount of sesame used by large households was 17.60 kilogram per hectare which was larger than 16.75 kilogram per hectare in medium households and 17.19 kilogram per hectare in small households. The maximum seed rate of all sampled farmers was 30.26 kilograms per hectare and minimum seed rate was 7.56 kilogram per hectare for all sampled farmers. The F-test showed that there was no significant difference in the amount of sesame seed used among three different farm households. In Table 4.13, the average amount of black sesame seed was 17.23 kilograms per hectare and that of white sesame was 17.22 kilograms per hectare. The independent t-test showed that there was no significant difference in seed use between black sesame and white sesame.

The various reasons taken into consideration by the households for choosing sesame varieties were listed in Figure 4.3. About 46.9% of the sample farmers selected sesame variety mainly based on high selling price; 39.2% of the farmers chose it based on high yield; about 33.8% based on suitable for soil followed by based on high quality, easy to practice, easy to sell, disease resistant and following others. Pearson Chi-square showed that there was significant difference only in the reason of following others in selecting variety among the sample farm households.

The available sesame seed sources of the sample farmers in the study area were (1) from the sale agents, (2) from local extension agents (3) from friends, neighbors or local market, (4) from their own farm from previous season and (5) from research farm (DAR). As shown in the Table 4.14, more than half of the sample farm households answered that main source of seed was from their own farm. Sources from friends, neighbors or local market were found as second available sources accepted by 34 farmers (26.2%) of sample farm households. Only 3.1% and 0.8% of sample farmers got from research farm (DAR) and extension agents, respectively. Pearson Chi-square showed that there was significant difference in receiving the seed from friend, neighbor and local market, and own farm among the sample farm households.

Table 4.13 Amount of sesame seed used for black sesame and white sesame

Sesame seed (kg/ha)	Black sesame (n = 63)	White sesame (n = 67)
Mean	17.23	17.22
Minimum	11.35	7.56
Maximum	30.26	30.26
t-test	$t = 0.016^{ns}$	

Note: ns = not significant

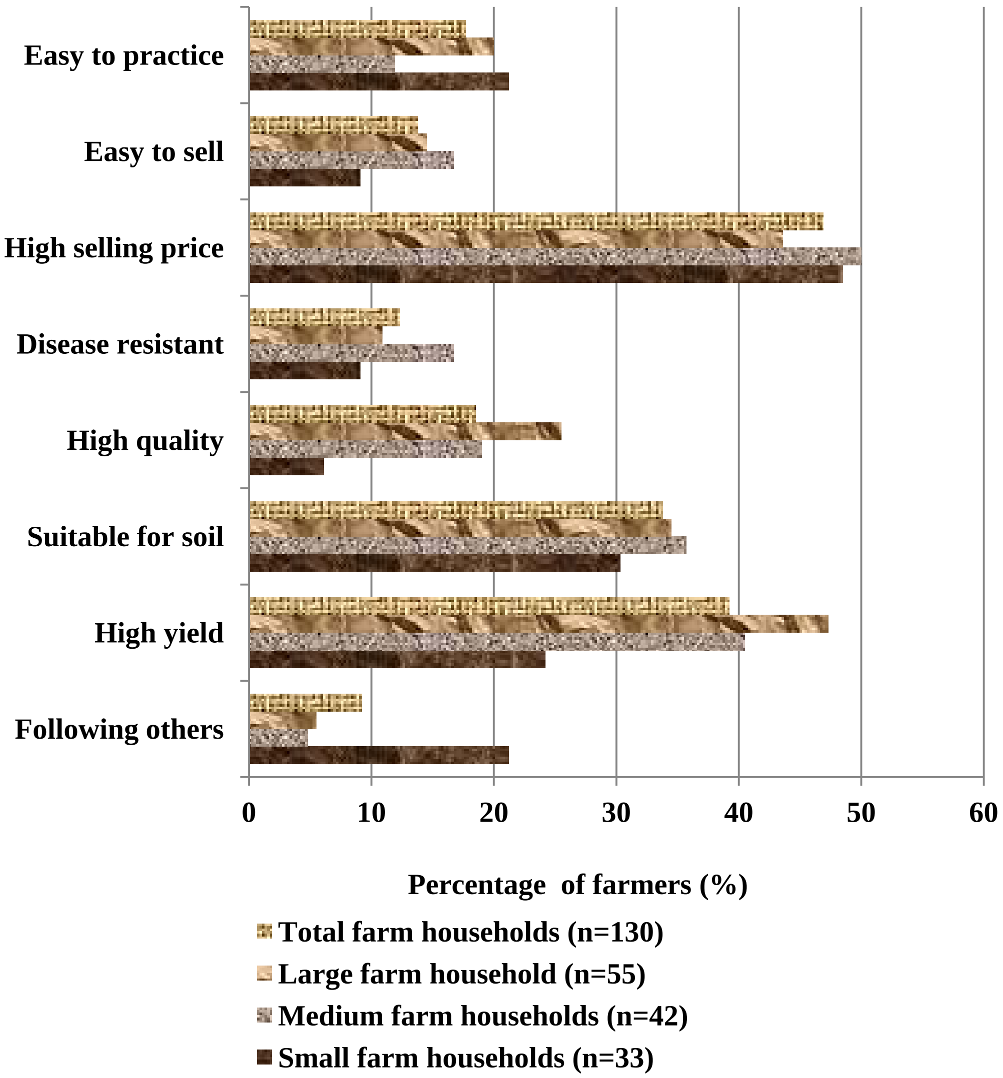


Figure 4.3 Reasons for selecting variety by different farm households

Table 4.14 Source of seed by different farm households

(Number of farmers)

Indicator	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
Sale agent	7 (21.2)	5 (11.9)	10 (18.2)	22 (16.9)
Pearson Chi-square	P = 0.536^{ns}			
Extension agent	0 (0)	0 (0)	1 (1.8)	1 (0.8)
Pearson Chi-square	P = 0.503^{ns}			
Friend, neighbor, local market	14 (42.4)	18 (42.9)	2 (3.6)	34 (26.2)
Pearson Chi-square	P = 0.000^{***}			
Own farm	12 (36.4)	21 (50.0)	42 (76.4)	75 (57.7)
Pearson Chi-square	P = 0.001^{***}			
Research farm (DAR)	0 (0)	0 (0)	4 (7.3)	4 (3.1)
Pearson Chi-square	P = 0.060^{ns}			

Note: Figures in the parentheses represent percentage.

*** is significant at 1% level and ns = not significant.

4.2.3 Fertilizer Application in Sesame Production

It was found that majority of farmers applied organic or chemical fertilizer in their sesame production in Table 4.15 and Table 4.16. They usually put farm yard manure (FYM) in their soil during land preparation and applied chemical fertilizer in two weeks after planting. Farm yard manure, especially cow dung was used as the organic fertilizer and urea fertilizer, compound fertilizer and Lachae fertilizer were used as inorganic fertilizers. There was significant difference in using compound and Lachae fertilizer among three different farm households.

All of the sample farmers used FYM. The average rate of FYM application in small farm household was 9.64 tons per hectare, 9.35 tons per hectare used by medium farmers and 9.99 tons per hectare applied by large farmers. The maximum rate of manure application was 30.89 tons per hectare and the minimum rate was 3.09 tons per hectare among all farms. The average rate of urea fertilizer in small, medium and large farm households were 110.12 kilogram per hectare, 106.98 kilogram per hectare and 83.83 kilogram per hectare, respectively. The F-test showed there was significant difference among urea fertilizer application among three different farm households. The maximum rate and minimum rate of urea fertilizer were 247.1 and 24.71 kilogram per hectare in all sample farmers. The small farmers used more urea fertilizer than medium and large farmers. The compound fertilizer was used by 60.60% of small farmers, 71.40% of medium farmers and 92.70% of large farmers. The average rate of compound fertilizer was 54.25 kilogram per hectare in small farm households, 72.39 kilogram per hectare in medium farm households and 98.93 kilogram per hectare in large farm households. The F-test indicated that there was highly significant difference in the use of compound fertilizer among the sample farm households. The maximum amount of compound fertilizer was 247.1 kilogram per hectare. Large farmers used more compound fertilizer than other two farm size groups. In the use of Lachae fertilizer, 12.10% of small farmers applied average rate of 18.71 kilogram per hectare, 35.70% of medium farmers used 44.36 kilogram per hectare and 20.00% of large farmers put in 28.64 kilogram per hectare. The maximum Lachae fertilizer rate was 247.1 kilogram per hectare. There was no significant difference among the use of Lachae fertilizer in three different farm households.

Table 4.15 Percentage of farmers using organic and inorganic fertilizers

(Number of farmers)

Item	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
FYM	33 (100)	42 (100)	55 (100)	130 (100)
Urea	33 (100)	42 (100)	55 (100)	130 (100)
Compound	20 (60.6)	30 (71.4)	51 (92.7)	101 (77.7)
Pearson Chi-square		P = 0.001***		
Lachae	4 (12.1)	15 (35.7)	11 (20.0)	30 (23.1)
Pearson Chi-square		P = 0.043**		

Note: Figures in the parentheses represent percentage.

and* are significant at 5% and 1% level respectively.

Table 4.16 Use of fertilizers in sesame production for different farm households

Item	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
FYM (ton/ha)				
Mean	9.64	9.35	9.99	9.69
Maximum	30.89	15.44	20.59	30.89
Minimum	3.09	3.09	5.15	3.09
F-test		F = 0.394[ns]		
Urea (kg/ha)				
Mean	110.12	106.98	83.83	97.99
Maximum	247.10	247.10	123.55	247.10
Minimum	24.71	24.71	24.71	24.71
F-test		F = 4.542**		
Compound (kg/ha)				
Mean	54.25	72.39	98.93	79.01
Maximum	123.55	247.10	247.10	247.10
Minimum	0	0	0	0
F-test		F = 7.789***		
Lachae (kg/ha)				
Mean	18.71	44.36	28.64	31.2
Maximum	185.32	247.10	247.10	247.10
Minimum	0	0	0	0
F-test		F = 1.732[ns]		

Figures in parenthesis are t values for the corresponding data.

and*are significant level at 5% and 1% level respectively and ns = not significant.

4.2.4 Pesticide and Foliar Application in Sesame Production

Farmers in the study area themselves make decisions on pest and disease management activities. Mostly, aphid, leaf binding caterpillar, root and stem rot of sesame and sesamum phyllody are the main pest and disease attack on the sesame production in the study area.

Farmers usually applied insecticides and pesticides for crop protection at least once in crop season by using sprayer. Most popular insecticides and pesticides applied for sesame production in the study areas were Force 10, Dozer and Acephate. Most of the farmers sprayed foliar fertilizers such as Comet, Moralmone, Booster and Shwe Tonic. Farmers usually used pesticide mixed with foliar fertilizer.

The pesticide and foliar application was mentioned in Table 4.17 and Table 4.18. The liquid form of pesticide was applied by 33.3% of small farmers, 31.0% of medium farmers and 61.8% of large farmers. Pearson Chi-square showed that there was significant difference in the use of pesticide liquid form among different farm households. The average amount of pesticide was 0.32 liter per hectare, 0.29 liter per hectare and 0.7 liter per hectare in small, medium and large farm households respectively. The maximum amount of pesticide was 1.73 liter per hectare. The F-test showed that there was highly significant difference in liquid form of pesticide among these three different farm households. The powder form of pesticide was applied by 40.6% of small farmers, 41.5% of medium farmers and 38.2% of large farmers. The average amount of pesticide was 0.29 kilogram per hectare, 0.41 kilogram per hectare and 0.3 kilogram per hectare in small, medium and large farm households respectively. The maximum amount of pesticide was 1.85 kilogram per hectare. It was found that large farmers used more pesticide in liquid form and medium farmers used more pesticide in powder form.

There were 57 total farmers used foliar fertilizer liquid form and 56 total farmers sprayed foliar powder form. And then, there was no significant difference in the use of two types of foliar fertilizer among small, medium and large farm households.

Table 4.17 Numbers of farmers using pesticides and foliar by sample farm households

(Number of farmers)

Item	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm household (n = 55)	Total farm households (n = 130)
Pesticide 1 (liquid)	11 (33.3)	13 (31.0)	34 (61.8)	72 (55.4)
Pearson Chi-square	P = 0.003***			
Pesticide 2 (powder)	13 (40.6)	17 (41.5)	21 (38.2)	51 (39.8)
Pearson Chi-square	P = 0.964[ns]			
foliar 1 (liquid)	16 (48.5)	15 (35.7)	26 (47.3)	57 (43.8)
Pearson Chi-square	P = 0.432[ns]			
Foliar 2 (powder)	13 (40.6)	16 (38.1)	27 (49.1)	56 (43.4)
Pearson Chi-square	P = 0.492[ns]			

Note: Figures in the parentheses represent percentage.

*** is significant at 1% level and ns = not significant.

Table 4.18 Use of pesticides in sesame production for different farm households

Item	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
Pesticide 1 (liter/ha)				
Mean	0.32	0.29	0.7	0.47
Maximum	1.24	1.24	1.73	1.73
Minimum	0	0	0	0
F-test		$F = 8.597^{***}$		
Pesticide 2 (kg/ha)				
Mean	0.29	0.41	0.3	0.33
Maximum	1.24	1.85	1.24	1.85
Minimum	0	0	0	0
F-test		$F = 0.824^{ns}$		
Foliar 1 (liter/ha)				
Mean	0.23	0.19	0.2	0.21
Maximum	1.58	1.24	1.24	1.58
Minimum	0	0	0	0
F-test		$F = 0.084^{ns}$		
Foliar 2 (kg/ha)				
Mean	0.56	0.48	0.76	0.62
Maximum	2.47	4.20	2.47	4.20
Minimum	0	0	0	0
F-test		$F = 1.423^{ns}$		

Note: *** is significant level at 1% level and ns = not significant.

4.2.5 Labour Utility and Farming Practices in Sesame Production

There are two types of labor: animal labor and human labor. Animal labor is used in land preparation and intercultivation. Human labor is used in sowing, fertilizer and pesticide application, weeding, and harvesting and threshing. There are two sources of labor used for sesame production. The main source of labor is family labor. Hired labor is also used as additional labor for land preparation, weeding, pesticide application and harvesting activities in the study areas.

Allocation and use of family labour and hired labor in sesame production were expressed in Table 4.19 and Table 4.20. In Table 4.19, medium and large farmers used average own animal labor 15 and 14 animal days and small farmers could use less own animal labor. The percentage share of the own animal labor was the largest in large farm households (88.06% of the total animal labor). The percentage of hired animal labor was the largest in small farm households (46.00% of the total animal labor) because they possessed few bullock which can be used in farming. The total animal labor measured as animal days in small, medium and large farm households were 18.89, 20.88 and 16.17 animal days respectively. The F-test showed that there was significant difference in family and hired animal labor used by different farm households.

In the use of human family labor, small farmers used 8.16 man days, medium farmers 9 man days and large farmers 4 man days. Small farmers hired human labor about 98 mandays, medium farmers 101 man days and large farmers 106 man days. In human labor use, there was significant difference in family labor used and no significant difference in hired labor used among small, medium and large farm households.

Farmers in the study area took place cleaning the residual parts of previous cropping season from December to February. Land preparation generally starts from the end of April or early May in rainy season. And then, spreading FYM is done in March by harrowing their plots three to four times with a four or five-tooth harrow pulled by a pair of bullock and they wait for the first shower. The land preparation is needed till the soil obtains a smooth and fine structure that is adequate for small sesame seeds to germinate.

Farmers prepared and ploughed their lands with a range of 7 to 10 days before cultivating under rain-fed condition. There are a few sample farmers using machine for land preparation in the sesame production of the rain-fed area. The machine for sesame production is still poor in the study area. In Table 4.20, land preparation with machine was done by large farm households (0.36 machine day). Small and medium farmers used average amount of 3 man days per hectare for seed sowing and large farmers used average amount of 3 man days per hectare. The maximum amount of human labor in sowing was 5 man days per hectare.

Weeding was started in one month after sowing sesame seeds. Farmers in the study area cleaned weeds at least two times in sesame cultivation. In the study area average man day of weeding for the total farmers was 55 man days pre hectare, maximum was 123.65 man days per hectare and minimum was 22 man days per hectare. Fertilizer application was done in average 5 times per hectare. Farmers used one person at a time in fertilizer application. Average man day of fertilizer application for total farm households was 5 man days and maximum amount was 7 man days per hectare. Average man day of pesticide application in large farm households was the highest (9 man day per hectare) and that of small farm household was the lowest (5 man days per hectare).

Depending on the life period of sesame variety, when the sesame plant or whole field of sesame is attaining a golden hue, it is time for harvesting. There are three processes in the harvesting as stacking (piling of the harvested sesame stalks), the elevation of stems for drying and thrashing and winnowing. All processes are done manually. In the study area, hired labors were used for harvesting, stacking, elevation of sesame crop, thrashing and winnowing. Therefore, harvesting and thrashing was done by the average of 40 man days. The F-test showed that there was significant difference in land preparation with animal, land preparation with machine and pesticide application among three different farm households.

The percentage share of labor use was clearly shown in Figure 4.4, 4.5 and 4.6. labor use for weeding possessed the largest proportion of total labor followed by harvesting and thrashing, land preparation, pesticide application and fertilizer application in all sample households.

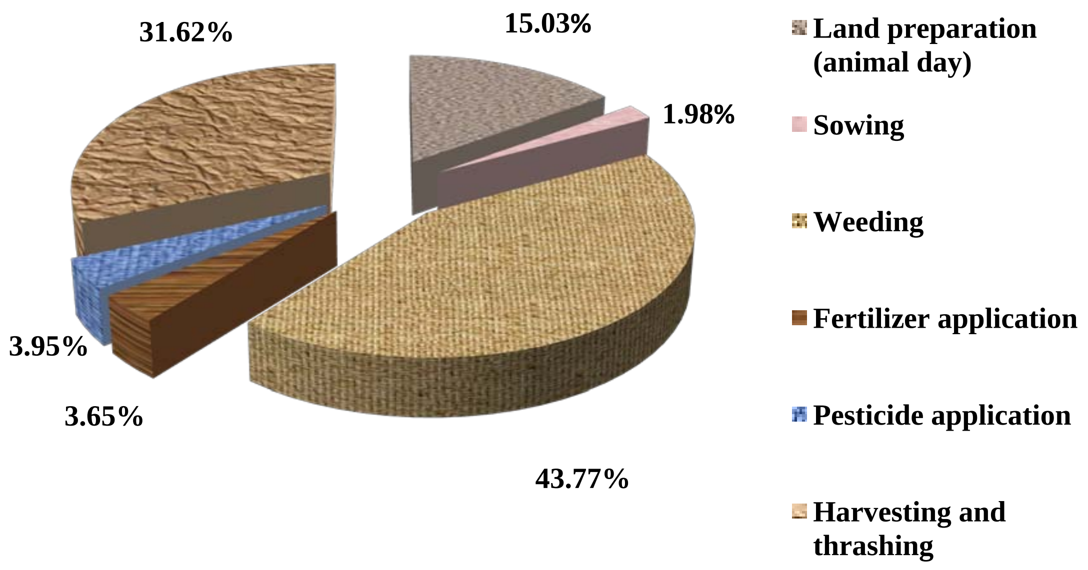


Figure 4.4 Structure of labor in sesame production for small farm households

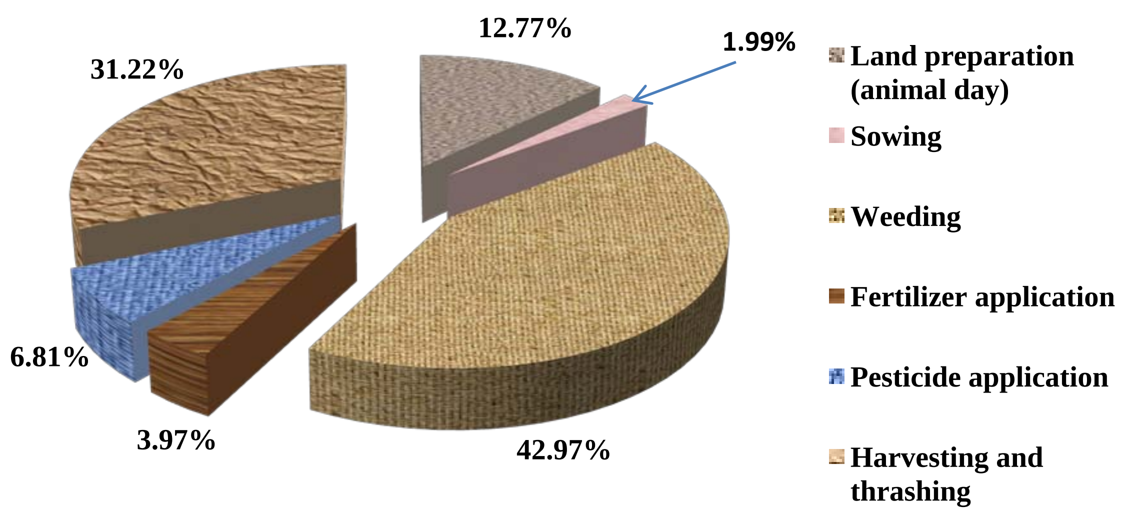


Figure 4.5 Structure of labor in sesame production for medium farm households

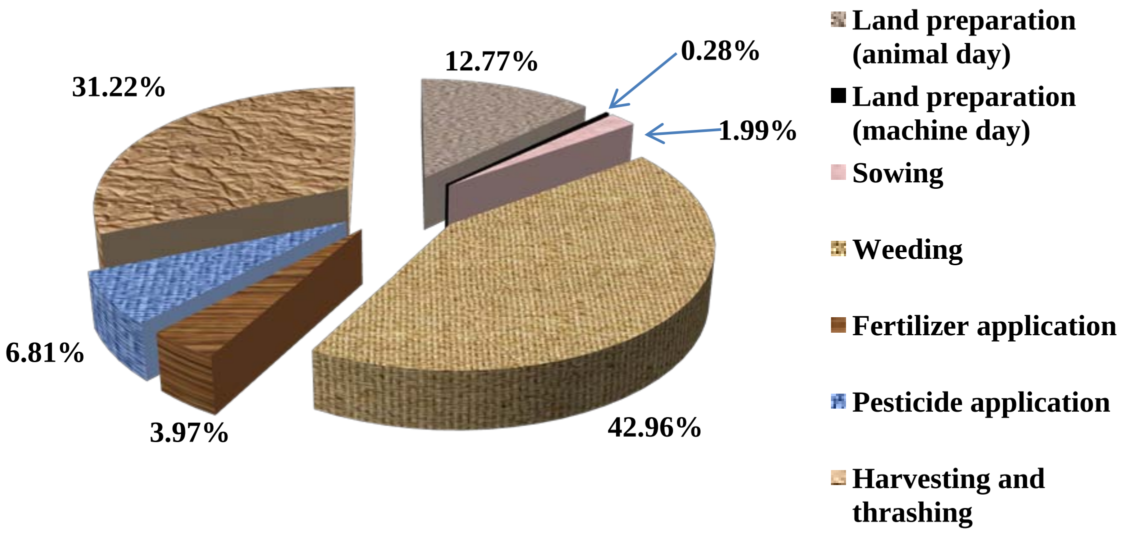


Figure 4.6 Structure of labor in sesame production for large farm households

Table 4.19 Allocation of family and hired labor in sesame production

Type of labor	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
Family labor (animal day)	10.11	14.88	14.24	13.40
F-test		F = 3.908**		
Ratio in total animal labor (%)	53.52	71.26	88.06	72.98
Hired labor (animal day)	8.69	6.00	1.93	4.96
F-test		F = 10.764***		
Ratio in total animal labor (%)	46.00	28.74	11.94	27.02
Total animal day	**18.89**	**20.88**	**16.17**	**18.36**
Family labor (man day)	8.16	8.83	4.10	6.67
F-test		F = 3.437**		
Ratio in total human labor (%)	7.68	8.04	3.72	6.12
Hired labor (man day)	98.09	100.95	105.98	102.36
F-test		F = 2.029ns		
Ratio in total human labor (%)	92.32	91.96	96.28	93.88
Total man day	**106.25**	**109.78**	**110.08**	**109.03**

Note: **and*** are significant at 5% and 1% level respectively and ns = not significant.

Table 4.20 Labor use in sesame production by different farm size groups

Activity	Measure-ment	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
Land preparation	Mean	18.79	20.89	16.17	18.36
(animal day)	Maximum	27.18	29.65	27.18	29.65
	Minimum	12.36	9.88	9.88	9.88
F-test		$F = 13.559^{***}$			
Land preparation	Mean	0.00	0.00	0.36	0.15
(machine day)	Maximum	0.00	0.00	2.47	2.47
	Minimum	0.00	0.00	0.00	0.00
F-test		$F = 6.236^{***}$			
Sowing (man day)	Mean	2.47	2.47	2.52	2.49
	Maximum	2.47	2.47	4.94	4.94
	Minimum	2.47	2.47	2.47	2.47
F-test		$F = 0.678^{ns}$			
Weeding (man day)	Mean	54.74	57.24	54.41	55.41
	Maximum	96.37	123.55	74.13	123.65
	Minimum	29.65	32.12	22.24	22.24
F-test		$F = 0.409^{ns}$			
Fertilizer application	Mean	4.57	5.12	5.03	4.94
(man day)	Maximum	7.41	7.41	7.41	7.41
	Minimum	0.00	2.47	2.47	0.00
F-test		$F = 1.475^{ns}$			
Pesticide application	Mean	4.94	5.41	8.63	6.65
(man day)	Maximum	7.41	17.30	17.30	17.30
	Minimum	0.00	0.00	0.00	0.00
F-test		$F = 11.965^{***}$			
Harvesting and	Mean	39.54	39.54	39.54	39.54
Thrashing	Maximum	39.54	39.54	39.54	39.54
(man day)	Minimum	39.54	39.54	39.54	39.54

Note: *** is significant at 1% level and ns = not significant.

4.2.6 Access to Extension Services

The agricultural extension division is responsible for disseminating information on technical progress to farmers, providing training on crop management, conducting agricultural development programs for hybrid varieties and others. Farmers were asked whether they have received extension services about sesame production in the study area. All of the sample farmers answered that access to government extension service is absent. However, agricultural information was received through private agro-chemical (fertilizers, pesticides, foliar, plant growth hormone, etc.) dealers and marketing agents. The pesticide and fertilizer company staff used to come to the villages once or twice within a crop season and they used to hold pesticide and fertilizer market promotion meetings in the villages.

4.2.7 Credit Availability

Availability of credit for sample farmers was shown in Table 4.21. There were three credit sources available for farmers in the study area. The credit received from all sources was for producing all rain-fed crops and for household expenses. Small, medium and large farmers borrowed money from MADB about average amount of 82,308 kyats per year, 97,576 kyats per year and 109,216 kyats per year by an interest rate of 1.5%, respectively. The average amount 420,000 kyats, 750,952 kyats and 1,930,000 kyats were borrowed from private money lenders such as shopkeepers in the villages, broker-men and crop traders by the interest rate 7 to 15% by the sample farm households. Small farmers borrowed average amount 200,000 kyats in a year, medium farmers borrowed 203,846 kyats per year and large farmers borrowed 208,333 kyats per year from Pact Myanmar by the interest rate of 2%. Farmers usually borrow cash to purchase inputs for sesame production such as seed, chemical fertilizer and pesticides in their village. The F-test showed that there was significant difference in the amount of credit taken from different sources among three different farm households.

Table 4.21 Amount of credit from different sources by farm size groups

(Kyat/year)

Source	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
MADB	82,307.69	97,575.76	109,215.67	101,649.49
F-test		$F = 19.143^{***}$		
Money lender	420,000.00	750,952.38	1,930,000.00	1,148,735.63
F-test		$F = 4.999^{**}$		
Pact Myanmar	200,000.00	203,846.15	208,333.33	203,333.33
F-test		$F = 4.913^{**}$		

Note: **and *** are significant at 5% and 1% level respectively.

4.3 Cost and Return Analysis for Sesame Production

The enterprise budget for sesame production among three different farm size groups was presented in Table 4.22. It was found that medium farm size group expensed maximum total variable cost (350,973 kyat/ha) and small farm size group expensed minimum total variable cost (332,388 kyat/ha). Maximum yield was obtained from large farm size group (767.99 kg/ha) and minimum yield was obtained from small farm size group (581.31 kg/ha). Total gross benefits for large farm size group was maximum (693,326 kyat/ha) and small farm size group was minimum (525,440 kyat/ha).

Total material cost was the highest in large farm households of 142,921 kyats per hectare and the lowest in small farm households of 131,279 kyats per hectare. Total family labor cost was the highest in medium farm households and the lowest in small farm households. It was expensed for the hired labor cost of 136,803 kyats per hectare in small farm households, 128,798 kyats per hectare in medium farm households and 120,868 kyats per hectare in large farm households. In the total interest cost on cash cost, large farm households expended the lowest amount and medium farm households expended the highest amount. Return above variable cash cost (RAVCC) were 237,252 kyats per hectare in small farm households, 306,808.33 kyat per hectare in medium farm households and 409,751 kyats per hectare in large farm households. Return above variable cost (RAVC) for small farm households, medium farm households and large farm households were 193,052 kyats per hectare, 246,448 kyats per hectare and 354,656 kyats per hectare respectively. Hence, the benefit-cost ratios were 1.58, 1.70 and 2.05 for small, medium and large farm households, respectively. The F-test showed that there was significant difference in benefit-cost ratios received among three different farm size groups. Therefore, it can be concluded that large farmers received more profit than small and medium farmers by growing sesame crop in the study area. The reason for receiving larger profit than small and medium farmers was that the large farmers got higher yield than the other two. Although there was not much different in output price and total variable costs among three different farm size groups, the profit received by all farm size groups was different.

The enterprise budget for black sesame and white sesame production was indicated in Table 4.23. The total variable cost of black sesame production

(350,950 kyat/ha) was higher than that of the white sesame production (331,667 kyat/ha). White sesame growing farmers obtained higher yield 694.57 kilograms per hectare than black sesame growing farmers who obtained the yield 644.53 kilograms per hectare. But price of black sesame (1,018 kyat/kg) was higher than that of the white sesame (841 kyat/kg).

Total material cost and total hired labor cost of black sesame growing farmers were higher than those of the white sesame growing farmers. But total family labor cost was higher in white sesame growing farmers than in black sesame growing farmers. Return above variable cash cost (RAVCC) was received 356,920 kyats per hectare from black sesame production and 308,244 kyat per hectare from white sesame production. Return above variable cost (RAVC) for black sesame growing farmers and white sesame growing farmers were 304,910 kyats per hectare and 252,494 kyats per hectare respectively. Therefore, the black sesame and white sesame growing farmers obtained the benefit-cost ratio of 1.87 and 1.76 respectively. The independent t-test showed that there was not significantly different in benefit-cost ratios between black sesame production and white sesame production.

Table 4.22 Enterprise budget of sesame among three different farm size groups (per ha basis)

Item	Small farmers (n = 33)	Medium farmers (n = 42)	Large farmers (n = 55)
1.Gross Benefit			
Total gross benefit	**525,440.30**	**597,420.91**	**693,326.01**
2. Variable Cost			
(a) Material Cost			
Seed	22,435.87	23,547.49	21,408.29
FYM	34,020.00	33,120.00	35,964.00
Fertilizer(Urea)	42,852.00	42,556.00	32,456.00
Fertilizer (Compound)	18,445.00	24,612.60	33,636.20
Lachae fertilizer	2,246.40	5,323.20	3,436.80
Pesticide 1	3,200.00	2,900.00	7,000.00
Pesticide 2	4,640.00	6,560.00	4,800.00
Foliar 1	920.00	760.00	800.00
Foliar 2	2,520.00	2,160.00	3,420.00
Total Material Cost(a)	**131,279.27**	**141,539.29**	**142,921.29**
(b)Family Labor Cost			
Plowing with machine	0.00	0.00	1,800.00
Plowing with draft cattle	12,350.00	15,600.00	15,500.00
Harrowing with draft cattle	22,920.00	35,310.00	33,420.00
Seeding	1,230.00	1,860.00	735.00
Fertilizer application	1,800.00	2,590.00	1,080.00
Pesticide application	1,950.00	1,650.00	1,080.00
Manual Weeding	3,950.00	3,350.00	1,480.00
Total family labor cost(b)	**44,200.00**	**60,360.00**	**55,095.00**
(c) Hired Labor Cost			
Plowing with draft cattle	9,750.00	3,250.00	450.00
Harrowing with draft cattle	20,220.00	16,050.00	5,520.00
Seeding	2,475.00	1,860.00	3,030.00
Fertilizer application	2,770.00	2,530.00	3,950.00
Pesticide application	3,000.00	3,770.00	7,550.00
Manual Weeding	51,140.00	53,890.00	52,920.00
Harvesting &Thrashing	47,448.00	47,448.00	47,448.00
Total Hired Labor Cost	**136,803.00**	**128,798.000**	**120,868.000**
(d) Interest on cash cost			
Material cost	9,845.95	10,615.45	10,719.10
Hired labor cost	10,260.23	9,659.85	9,065.10
Interest on cash cost	**20,106.17**	**20,275.30**	**19,784.20**
Total variable cost (TVC)	**332,388.44**	**350,972.58**	**338,668.48**
Return above cash cost (RAVCC)	**237,251.85**	**306,808.33**	**409,750.72**
Return above variable cost (RAVC)	**193,051.85**	**246,448.33**	**354,655.72**
Return per unit of capital invested (BCR)	**1.58**	**1.70**	**2.05**
F-test		**F = 5.779*** **	

Note: *** is significant different at 1% level.

Table 4.23 Enterprise budget of black sesame and white sesame production (per ha basis)

Item	Black sesame(n = 63)	White sesame (n = 67)
1.Gross Benefit		
Total gross benefit	**655,860.84**	**584,161.15**
2. Variable Cost		
(a) Material Cost		
Seed	27,967.91	17,156.80
FYM	31,428.00	37,512.00
Fertilizer(Urea)	44,548.00	32,540.00
Fertilizer (Compound)	23,572.20	29,964.20
Lachae fertilizer	5,490.00	2,102.40
Pesticide 1	4,300.00	5,100.00
Pesticide 2	4,000.00	6,560.00
Foliar 1	800.00	840.00
Foliar 2	1,935.00	3,600.00
Total Material Cost(a)	**144,041.11**	**135,375.40**
(b)Family Labor Cost		
Plowing with machine	0.00	1,500.00
Plowing with draft cattle	11,350.00	17,900.00
Harrowing with draft cattle	32,580.00	30,210.00
Seeding	1,410.00	1,050.00
Fertilizer application	1,960.00	1,550.00
Pesticide application	1,570.00	1,400.00
Manual Weeding	3,140.00	2,140.00
Total family labor cost(b)	**52,010.00**	**55,750.00**
(c) Hired Labor Cost		
Plowing with machine		
Plowing with draft cattle	6,650.00	900.00
Harrowing with draft cattle	17,520.00	8,070.00
Seeding	2,295.00	2,715.00
Fertilizer application	3,100.00	3,280.00
Pesticide application	3,960.00	6,310.00
Manual Weeding	53,070.00	52,520.00
Harvesting &Thrashing	47,448.00	47,448.00
Total Hired Labor Cost	**134,043.00**	**121,243.00**
(d) Interest on cash cost		
Material cost	10,803.08	10,153.16
Hired labor cost	10,053.23	9,145.73
Interest on cash cost	**20,856.31**	**19,298.88**
Total variable cost (TVC)	**350,950.42**	**331,667.28**
Return above cash cost (RAVCC)	**356,920.42**	**308,243.87**
Return above variable cost (RAVC)	**304,910.42**	**252,493.87**
Return per unit of capital invested (BCR)	**1.87**	**1.76**
t-test	**$t = 1.283^{ns}$**	

Note: ns = not significant

4.4 Factor Share Analysis

The factor shares in payments and percentages of the sample households were presented in Table 4.24. The factor shares of variable input, labor input and interest for all sample farmers were 22.46%, 29.95% and 3.22% respectively. Therefore gross margin factor share was 44.37% and farm income factor share was 53.80% for all sample farmers. Factor share for variable inputs, labor inputs and interest for small farm size were 24.99%, 34.45% and 3.83%. Therefore, gross margin factor share for small farm size group was 36.74% and farm income factor share for small farm size group was 45.15%. The medium farm size group received factor shares of variable inputs (23.69%), labor input (31.66%), interest (3.39%), gross margin (41.26%) and farm income factor share (51.36%). The large farmers occupied factor shares for variable inputs (20.62%), labor inputs (25.38%), interest (2.85%) and gross margin of 51.15%. Therefore, farm income factor share for large farm size group was 59.10%. Among three different farm size groups, large farmers received higher factor shares for farm income than those of the medium and small farm size groups.

Factor shares for variable inputs, labor inputs, interest and gross margin for black sesame were 21.96%, 28.37%, 3.18% and 46.49% respectively as shown in Table 4.25. Therefore, farm income factor share for black sesame was 54.42%. The white sesame farmers received factor shares of variable inputs (23.18%), labor input (30.30%), interest (3.30%), gross margin (43.22%) and farm income factor share was 52.76%. Therefore, black sesame growing farmers received higher factor shares for farm income than that of the white sesame growing farmers.

Table 4.24 Comparison of factor shares among different farm size groups

Variables	Small farm households (n = 33)		Medium farm households (n = 42)		Large farm households (n = 55)		Total farm households (n = 130)	
	Factor share payment (ks/ha)	Factor share (%)	Factor share payment (ks/ha)	Factor share (%)	Factor share payment (ks/ha)	Factor share (%)	Factor share payment (ks/ha)	Factor share (%)
Total Revenue	525,440	100.00	597,420	100.00	693,323	100.00	621,111	100.00
Variable Input Cost	131,279	**24.99**	141,539	**23.69**	142,921	**20.62**	139,525	**22.46**
Seeds	22,435	4.27	23,547	3.94	21,408	3.09	22,388	3.60
Fertilizers	97,563	18.57	105,611	17.68	105,493	15.22	103,527	16.71
Chemicals	11,280	2.15	12,380	2.07	16,020	2.31	13,610	2.19
Labor Cost	181,003	**34.45**	189,158	**31.66**	175,963	**25.38**	186,033	**29.95**
Family labor	44,200	8.41	60,360	10.10	55,095	7.95	58,580	9.43
Hired labor	136,803	26.04	128,798	21.56	120,868	17.43	127,453	20.52
Interest Cost	20,106	**3.83**	20,275	**3.39**	19,784	**2.85**	20,023	**3.22**
Total Inputs	332,388	63.26	350,972	58.74	338,668	48.85	345,582	55.63
Gross Margin	193,051	36.74	246,448	41.26	354,655	51.15	275,529	44.37
Farmer's Farm Income	237,252	45.15	306,808	51.36	409,750	59.10	334,109	53.80

Note: Farmer's Farm income = Gross Margin + Family Labor Cost

Table 4.25 Comparison of factor shares between black sesame and white sesame production

Variables	Black sesame (n = 63)		White sesame (n = 67)	
	factor share payment (ks/ha)	Factor share (%)	factor share payment (ks/ha)	Factor share (%)
Total Revenue	655,860	100.00	584,161	100.00
Variable Input Cost	144,041	**21.96**	135,375	**23.18**
Seeds	27,967	4.26	17,156	2.94
Fertilizers	105,038	16.02	102,118	17.48
Chemicals	11,035	1.68	16,100	2.76
Labor Cost	186,053	**28.37**	176,993	**30.30**
Family labor	52,010	7.93	55,750	9.54
Hired labor	134,043	20.44	121,243	20.76
Interest Cost	27,888	**3.18**	25,731	**3.30**
Total Inputs	350,950	53.51	331,667	56.78
Gross Margin	304,910	46.49	252,493	43.22
Farmer's Farm Income	356,920	54.42	308,243	52.76

Note: Farmer's Farm Income = Gross Margin + Family Labor Cost

4.5 Technical Efficiency Measurement for Rain-fed Sesame Production

4.5.1 Summary Statistics of the Variables for All Sesame Farmers

The detailed summaries of the variables involved in the frontier production function of the sample sesame growing farmers in small, medium and large farm sizes were described in Table 4.26. Based on the survey data, average yield of sesame for small farmers was 581.31 kilograms per hectare, for medium farmers 612.35 kilograms per hectare and for large farmers 767.99 kilograms per hectare. For all farmers, the average yield of sesame was 670.32 kilograms per hectare ranging from 121.03 to 1331.33 kilograms per hectare.

Small farmers applied the average amount of seed rate 16.96 kilograms per hectare, medium farmers 16.75 kilograms per hectare and large farmers 16.85 kilograms per hectare. For all farmers, average seed rate was 16.85 kilograms per hectare ranging from 7.56 to 30.26 kilograms per hectare.

The average amount of FYM used in sesame farming was 9.64 tons per hectare in small farmers, 9.35 tons per hectare in medium farmers and 9.99 tons per hectare in large farmers. The average amount of FYM for all farmers was 9.69 tons per hectare ranged from 3.09 to 30.89 tons per hectare.

The average amount of urea fertilizer used in small farmers was 110.12 kilograms per hectare, 106.98 kilograms per hectare in medium farmers and 83.83 kilograms per hectare in large farmers. The average amount of urea used by all farmers was 97.99 kilograms per hectare with a range of 24.71 to 247.10 kilograms per hectare.

Small farmers used average human labor of 106.25 man days per hectare in small farm, 109.78 man days per hectare in medium farm and 110.12 man days per hectare in large farm. As a whole, the average human labor of 109.03 man days was used with a range of 76.60 to 170.49 man days per hectare.

The average animal labor used in sesame farming including hired and family labors was noted 18.79 animal days per hectare in small farmers, 20.89 animal days per hectare in medium farmers and 16.17 animal days per hectare in large farmers. All farmers in the study area used average 18.36 animal days per hectare in sesame production ranging from 9.88 to 29.65 animal days.

The average farm size of all farm households was 5.21 hectares ranged from 0.40 hectares to 20.23 hectares. The average farm size of small, medium and large farm households were 1.48 hectares, 3.47 hectares and 8.79 hectares respectively.

The average schooling year for all farm households was 6.59 years with a range of monastery level (1 year) to graduate level (16 years). Small and medium farmers' schooling years were about 5 years. But the average schooling year of the large farmers was 8.47 years. Therefore the large farmers more educated than small and medium farmers.

The household's experience in sesame farming was a mean value of 24.62 years ranging from 2 years to 65 years of experience. Average farming experience of small, medium and large farmers was 17.64 years, 26.93 years and 27.05 years respectively. In this case, large farmers had more experience in sesame farming than small and medium farmers.

Table 4.26 Summary statistics of the variables for different farm size groups

Variables (unit)	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
Output variable				
Yield (kg/ha)	581.31 (121.03-1089.27)	612.35 (302.57-1089.27)	767.99 (423.60-1331.33)	670.32 (121.03-1331.33)
Input variables				
Seed rate (kg/ha)	16.96 (11.35-30.26)	16.75 (11.35-22.69)	16.85 (7.56-30.26)	16.85 (7.56-30.26)
FYM (ton/ha)	9.64 (3.09-30.89)	9.35 (3.09-15.44)	9.99 (5.15-20.59)	9.69 (3.09-30.89)
Urea fertilizer (kg/ha)	110.12 (24.71-247.10)	106.98 (24.71-247.10)	83.83 (24.71-123.55)	97.99 (24.71-247.10)
Man labor (man day/ha)	106.25 (81.54-150.73)	109.78 (79.01-170.50)	110.12 (76.61-138.38)	109.03 (76.60-170.49)
Animal labor (animal day/ha)	18.79 (12.36-27.18)	20.89 (9.88-29.65)	16.17 (9.88-27.18)	18.36 (9.88-29.65)
Variables for inefficiency effect				
Farm size (hectare)	1.48 (0.40-2.02)	3.47 (2.43-4.05)	8.79 (4.45-20.23)	5.21 (0.40-20.23)
Schooling years (year)	5.33 (1-12)	5.12 (1-16)	8.47 (1-16)	6.59 (1-16)
Farming experience (year)	17.64 (2-55)	26.93 (5-65)	27.05 (2-60)	24.62 (2-65)

Note: Figures in the parentheses represent range.

4.5.2 Estimation of Production Frontier and Technical Efficiency for All Sample Sesame Farmers

Parameters of ordinary least square (OLS) and maximum likelihood estimate (MLE) in stochastic frontier production function for sample sesame farmers were estimated using the FRONTIER 4.1 (Coelli, 1996). At this step, the Cobb–Douglas production function was expected to have a significant influence on output. The normally distributed random error (ν_i) and the half normal error term (μ_i) associated with the technical inefficiency were included in this function.

The parameter estimates of OLS and MLE for all sample farmers were indicated in Table 4.27. The value of likelihood ratio test of one-sided error was 27.63 and significant at $\alpha = 0.01$ level indicating that the goodness of fit of the model. The values of σ_s^2 and γ were statistically significant at $\alpha = 0.05$ level and $\alpha = 0.01$ level, respectively. γ value of 0.96 implied that the inefficiency effects highly determined the variability of sesame yield. Therefore 96% of difference between observed yield and maximum possible yield was due to the factors which were under farmer's control. The stochastic frontier analysis had further shown that 96% of observed inefficiency was due to the farmer's inefficiency in decision-making and only 4% of it was due to random factors outside their control in the case of all farms.

The determinants of output included in the stochastic frontier model were seed rate, manure (FYM), urea fertilizer, human labor, animal labor, farm size, farmer's schooling years and farming experience in sesame.

The coefficients of the input variables in the production function were elasticity of mean output with respect to the different inputs for Cobb-Douglas model, defined by equation (1) and (2). Results of the estimation of the frontier production functions (OLS) and (MLE) for all sample sesame production farmers were presented in Table 4.27. The empirical results indicated that the elasticity of frontier (best practice) production concerning seed rate was estimated to be positively related to yield of sesame and it was statistically significant at 5% level in OLS estimation but was not significant in MLE estimation. The estimated coefficient for manure (FYM) showed the positive relation to yield of sesame and it was statistically significant at 5% level in both OLS and MLE estimates. It can be concluded that if the farmers put in more FYM in sesame production, yield of sesame can be increased.

The estimated coefficient for human labor indicated positively related to yield of sesame and it was statistically significant at 5% level in OLS estimation and at 1% level in MLE estimation. It was indicated that if all farmers use more human labor, yield of sesame can be increased.

The estimates for urea and animal labor showed the negative relation to sesame yield. The estimated coefficient of urea fertilizer was not significant. However, the estimated coefficient of animal labor was statistically significant at 5% level in MLE estimates. It was shown that all farmers in the study area overused the draught power or inefficiently used animal labor.

For inefficiency model for all sample farmers, farm size, household head's schooling year and household head's experience in sesame farming were negatively related to inefficiency effect. The negative coefficient of household head's schooling year and household head's experience in sesame farming indicated that educated and well-experienced farmers were more efficient in sesame production.

Table 4.27 Parameters of Ordinary Least Square (OLS) and Maximum Likelihood Estimate (MLE) in stochastic frontier production function for all sample sesame farmers

Variables	Parameters	OLS	MLE
Stochastic frontier			
Constant	β_0	3.83*** (3.43)	4.2*** (3.64)
Seed rate	β_1	0.27** (2.02)	0.12ns (1.02)
Manure (FYM)	β_2	0.22** (2.44)	0.15** (2.21)
Urea fertilizer	β_3	-0.01ns (-0.16)	-0.02ns (-0.41)
Human labor	β_4	0.42** (1.96)	0.55***(2.49)
Animal labor	β_5	-0.19ns (-1.5)	-0.17** (-1.76)
Inefficiency model			
Constant	δ_0		0.5ns (1.28)
Farm size	δ_1		-0.21ns (-1.28)
Education level	δ_2		-0.01ns (-0.03)
Experience	δ_3		-0.04ns (-0.32)
Variance parameters			
$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$		0.13	0.28** (1.73)
$\gamma = \sigma_u^2 / \sigma_s^2$			0.96*** (23.39)
Log-likelihood		-47.93	-34.12
LR test; one-sided error			27.63***
$\chi^2_{(0.05)}$ (mixed Chi square distribution)			10.37
Mean technical efficiency			0.68
No. of observation		130	130

Note: Figures in parenthesis are t values for the corresponding data.

**, ***are significant level at 5% and 1% level respectively.

4.5.3 Comparison of Technical Efficiency (TE) in Different Farm Size Groups

The percent distribution of the efficiency estimates obtained from the stochastic frontier model was presented in Table 4.28 and in Figure 4.7. The detailed technical efficiency indices for all sample farmers; small farmers, medium farmers and large farmers were shown in Appendix 10, Appendix 11, Appendix 12 and Appendix 13 respectively and output from program the FRONTIER (version 4.1) for all sample farmers was shown in Appendix 16.

In Table 4.28, the technical efficiency of all sample farmers ranged from 0.11 to 1.00. The average technical efficiency of all farmers was 0.68. This implied that, on average, all farmers were able to obtain 68% of the potential (stochastic) frontier production level, given the levels of their inputs and the technology currently being used.

The technical efficiencies of individual farmers were categorized into the technical efficiencies for three different farm size groups. The mean technical efficiencies of small, medium and large farmers were 0.60, 0.65 and 0.74 respectively. This implied that, on average, small farmers, medium farmers and large farmers were able to obtain 60%, 65% and 74%, respectively, of the potential (stochastic) frontier production level, given the levels of their inputs and the existing technology.

About 15.38% of all sample farmers had the technical efficiency index less than and equal to technical efficiency of 0.50 (50%), 75.38% of all farmers had technical efficiency between 0.51 (51%) and 0.90 (90%), and only 9.24 % of all farmers had technical efficiency more than 0.90 (90%) as shown in Table 4.40 and in Figure 4.6. There was significant difference in technical efficiency among three different farm size groups. Large farmers were more technically efficient than medium and small farmers as a result of mean technical efficiency.

Percent distribution above and below mean technical efficiency for sample farmers was presented in Table 4.29. About 63.64% of small farmers, 57.14% of medium farmers and 38.18% of the large farmers had the technical efficiency below mean technical efficiency (0.68). About 30.30% of small farmers, 40.48% of medium farmers and 61.82% of large farmers had technical efficiency above 0.68. For all sample farmers, about 50.77% of farmers had technical efficiency below 0.68 which showed that those farmers considerable efficiently operated their farms. About 46.92% of farmers had technical efficiency above 0.68 which indicated that their production efficiency can be increased by using the present technology.

Table 4.28 Percent distribution of farm-specific technical efficiency of sesame farmers in Magway Township

Technical Efficiency Range	Small Farmers		Medium Farmers		Large Farmers		All Farmers	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
0.11-0.20	1	3.03	0	0.00	0	0.00	1	0.77
0.21-0.30	1	3.03	1	2.38	0	0.00	2	1.54
0.31-0.40	5	15.15	4	9.52	1	1.82	10	7.69
0.41-0.50	4	12.12	3	7.14	0	0.00	7	5.38
0.51-0.60	5	15.15	9	21.43	8	14.55	22	16.92
0.61-0.70	8	24.24	12	28.57	13	23.64	33	25.38
0.71-0.80	1	3.03	3	7.14	8	14.55	12	9.23
0.81-0.90	3	9.09	8	19.05	20	36.36	31	23.85
0.91-1.00	5	15.15	2	4.76	5	9.09	12	9.24
Total	33	100	42	100	55	100	130	100
Mean TE	0.60		0.65		0.74		0.68	
F-test			$F = 8.661^{***}$					
Maximum TE	0.94		0.93		0.95		0.95	
Minimum TE	0.16		0.27		0.35		0.16	

Note: *** is significant at 1% level.

Table 4.29 Percent distribution above and below average technical efficiency of sesame farmers

Technical Efficiency Range	Small Farmers		Medium Farmers		Large Farmers		All Farmers	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Below 0.68	21	63.64	24	57.14	21	38.18	66	50.77
0.68	2	6.06	1	2.38	0	0	3	2.31
Above 0.68	10	30.3	17	40.48	34	61.82	61	46.92
Total	33	100	42	100	55	100	130	100

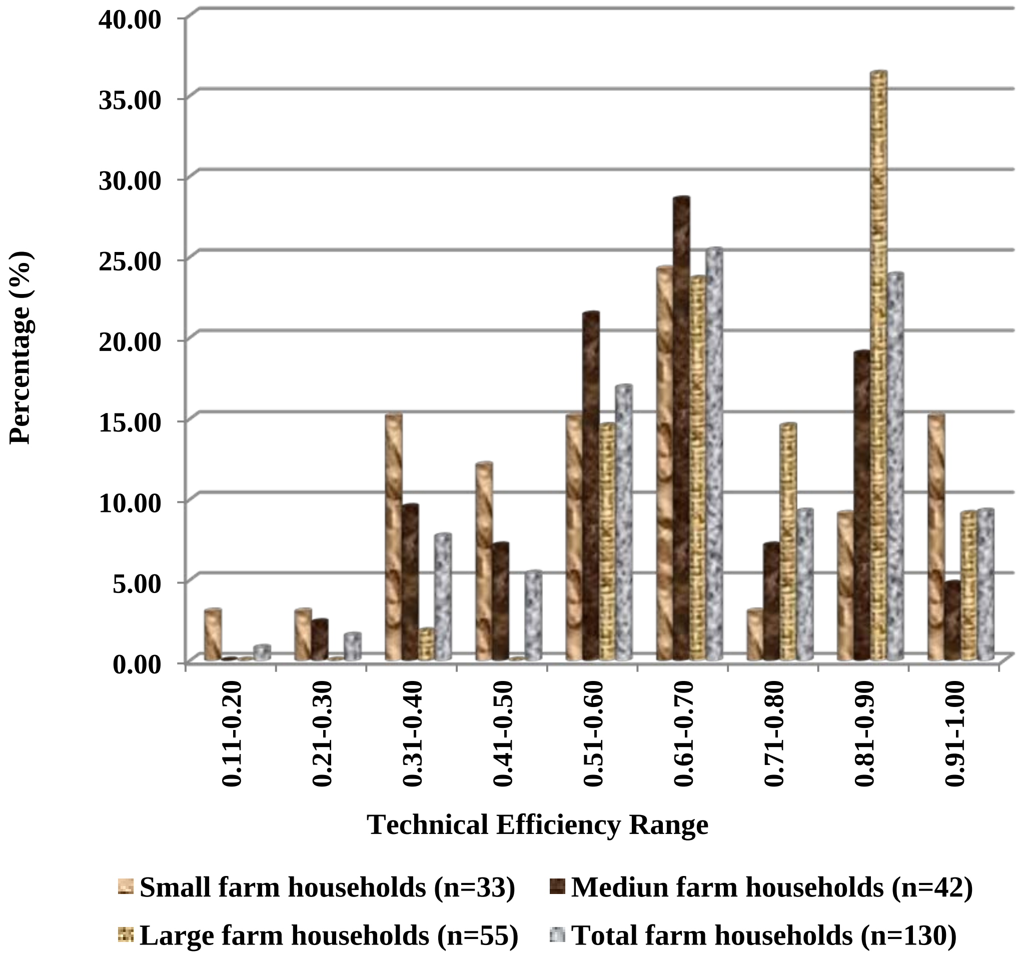


Figure 4.7 Percent distribution of farm-specific technical efficiency of sesame farmers in Magway Township

4.5.4 Summary Statistics of the Variables for Black Sesame Farmers and White Sesame Farmers

Table 4.30 revealed the summary statistics of the variables involved in the frontier production function of the sample sesame farmers in black sesame and white sesame production. Based on the survey data, the mean yield of sesame for black sesame farmers was 644.53 kilograms per hectare ranging from 121.03 to 1089.27 kilograms per hectare and for white sesame farmers was 694.57 kilograms per hectare with a range of 242.06 to 1331.33 kilograms per hectare.

Black sesame farmers applied the average amount of seed rate 17.23 kilograms per hectare ranged from 11.35 to 30.26 kilograms per hectare and white sesame farmers used 17.22 kilograms per hectare ranged from 7.56 to 30.26 kilograms per hectare. The average FYM used in sesame farming was 8.73 ton per hectare in black sesame farmers and 10.42 tons per hectare in white sesame farmers with a range of 3.09 to 20.59 tons per hectare and 5.15 to 30.89 tons per hectare respectively.

The urea fertilizer was used with a mean value of 111.37 kilograms per hectare in black sesame farmers ranging from 24.71 to 247.10 kilograms per hectare and 81.35 kilograms per hectare in white sesame farmers ranging from 24.71 to 123.55 kilograms per hectare. Black sesame farmers used average human labor of 108.80 man days per hectare with a range of 79.07 to 170.50 man days per hectare and white sesame farmers used 109.24 man days per hectare ranged from 76.60 to 150.73 man days per hectare. The average animal labor used in sesame farming including hired and family labors was 20.32 animal days per hectare in black sesame farmers and it was 16.52 animal days per hectare in white sesame farmers ranged from 12.36 to 29.65 animal days per hectare and 9.88 to 24.71 animal days per hectare respectively.

The black sesame farmers possessed the average farm size of 4.31 hectares with a range of 0.40 to 18.21 hectares and white sesame farmers occupied the average farm size of 6.07 hectares ranged from 0.40 to 20.23 hectares. The education level of black sesame farmers and of white sesame farmers was from monastery level (1 year) to graduate level (16 years). The average farming experience of black sesame farmers was 22.83 years and that of white sesame farmers was 26.28 years.

Table 4.30 Summary statistics of the variables for black sesame and white sesame production

Variables (unit)	Black sesame (n=63)	White sesame (n=67)
Output variable		
Yield (kg/ha)	644.53 (121.03-1089.27)	694.57 (242.06-1331.33)
Input variables		
Seed rate (kg/ha)	17.23 (11.35-30.26)	17.22 (7.56-30.26)
FYM (ton/ha)	8.73 (3.09-20.59)	10.42 (5.15-30.89)
Urea fertilizer (kg/ha)	111.37 (24.71-247.1)	81.35 (24.71-123.55)
Man labor (man day/ha)	108.80 (79.07-170.50)	109.24 (76.60-150.73)
Animal labor (animal day/ha)	20.32 (12.36-29.65)	16.52 (9.88-24.71)
Variables for inefficiency effect		
Farm size (hectare)	4.31 (0.40-18.21)	6.07 (0.40-20.23)
Schooling years (year)	6.51 (1-16)	7.73 (1-16)
Farming experience (year)	22.83 (2-65)	26.28 (26-78)

Note: Figures in the parentheses represent range.

4.5.5 Estimation of Production Frontier and Technical Efficiency for Black Sesame Farmers and White Sesame Farmers

The parameter estimates of OLS and MLE for black sesame and white sesame growing farmers were indicated in Table 4.31 and Table 4.32 respectively. In Table 4.31, the value of likelihood ratio test of one-sided error was 24.48 and significant at $\alpha = 0.01$ level indicating that the goodness of fit of the model. The values of σ_s^2 and γ were statistically significant at $\alpha = 0.01$ level. γ value of 0.99 implied that the inefficiency effects highly determined the variability of sesame yield. For white sesame farmers, the values of σ_s^2, γ and likelihood ratio test of one-sided error were statistically significant at $\alpha = 0.01$ level.

The determinants of output included in the stochastic frontier model for black sesame and white sesame production were also sesame yield, seed rate, manure (FYM), urea fertilizer, human labor, animal labor, farm size, farmer's schooling years and farming experience in sesame.

Results of the estimation of the frontier production functions (OLS) and (MLE) for black sesame farmers were presented in Table 4.31. The estimate of seed rate was positively related to yield of sesame and not significant in OLS estimation. The coefficient of seed rate was positively related to black sesame yield and it was statistically significant at 5% level in MLE estimation. It showed that the yield of black sesame can be increased if the farmers used more seed in black sesame production. The estimated coefficient for manure showed a positive relation to yield of black sesame and it was statistically significant at 1% level both in OLS and in MLE estimates. It can be concluded that if the farmers put in more FYM in black sesame production, the yield of that can be increased.

The estimated coefficient for urea and human labor indicated a positive relation to yield of black sesame but it was not statistically significant in both OLS estimation and MLE estimation. The estimated coefficient of animal labor showed a negative relation to sesame yield and it was statistically significant at 5% level in OLS estimate. It showed that all farmers in the study area overused the draft animal power or inefficiently used in animal labor.

In inefficiency model for black sesame farmers, farm size, household head's schooling year and his experience in sesame farming were negatively related to inefficiency effect. The negative coefficient of the household head's schooling year and his experience in sesame farming indicated that educated and well-experienced farmers were more efficient in black sesame production.

Results of the estimation of the frontier production functions (OLS) and (MLE) for white sesame production were presented in Table 4.32. The coefficients of seed rate and manure were positively related to yield and were not significant in both OLS and MLE estimation. The coefficient of urea fertilizer showed a positive relation to yield of white sesame both in OLS estimate and MLE estimate. The estimated coefficient for human labor was positively and statistically significant at 5% level in OLS estimation and at 1% level in MLE estimation. The coefficient of animal labor showed a negative relation to white sesame yield.

In inefficiency model for white sampled farmers, the estimate of farmer's schooling years was positively related to yield. The coefficients of farm size and the household head's experience in sesame farming were negatively influenced on yield. It indicated that well-experienced farmers were more efficient in white sesame production.

Table 4.31 Parameters of Ordinary Least Square (OLS) and Maximum Likelihood Estimate (MLE) in stochastic frontier production function for black sesame farmers

Variables	Parameter	OLS	MLE
Stochastic frontier			
Constant	β_0	5.22*** (2.76)	6.52*** (8.08)
Seed rate	β_1	0.28^{ns} (1.38)	0.19** (1.83)
Manure (FYM)	β_2	0.27*** (3.3)	0.23*** (4.2)
Urea fertilizer	β_3	0.04^{ns} (0.71)	0.05^{ns} (1.71)
Human labor	β_4	0.15^{ns} (0.47)	0.11^{ns} (0.96)
Animal labor	β_5	-0.35** (-1.84)	-0.12^{ns} (-1.34)
Inefficiency model			
Constant	δ_0		1.07^{ns} (3.46)
Farm size	δ_1		-0.1^{ns} (-0.42)
Education level	δ_2		-0.29** (-1.77)
Experience	δ_3		-0.27** (-2.19)
Variance parameters			
$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$		0.13	0.41*** (3.27)
$\gamma = \sigma_u^2 / \sigma_s^2$			0.99***(630006.03)
Log-likelihood		-21.68	-9.4
LR test; one-sided error			24.48***
$\chi^2_{(0.05)}$ (mixed Chi square distribution)			10.37
Mean technical efficiency			0.67
No. of observation		63	63

Note: Figures in parenthesis are t values for the corresponding data.

**, ***are significant level at 5% and 1% level respectively.

Table 4.32 Parameters of Ordinary Least Square (OLS) and Maximum Likelihood Estimate (MLE) in stochastic frontier production function for white sesame farmers

Variables	Parameter	OLS	MLE
Stochastic frontier			
Constant	β_0	2.99** (2.11)	3.46*** (2.5)
Seed rate	β_1	0.27^{ns} (1.54)	0.12^{ns} (0.71)
Manure	β_2	0.01^{ns} (0.13)	0.05^{ns} (0.44)
Urea fertilizer	β_3	0.01^{ns} (0.28)	0.001^{ns} (0.07)
Human labor	β_4	0.63** (2.04)	0.73*** (2.61)
Animal labor	β_5	-0.1^{ns} (-0.5)	-0.14^{ns} (-0.8)
Inefficiency model			
Constant	δ_0		0.61^{ns} (1.43)
Farm size	δ_1		-0.23** (-2.03)
Education level	δ_2		0.2^{ns} (1.37)
Experience	δ_3		-0.1^{ns} (-1.01)
Variance parameters			
$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$		0.12	0.15*** (2.52)
$\gamma = \sigma_u^2 / \sigma_s^2$			0.90*** (5.89)
Log-likelihood		-22.55	-13.70
LR test; one-sided error			17.70***
$\chi^2_{(0.05)}$ (mixed Chi square distribution)			10.37
Mean technical efficiency			0.66
No. of observation			67

Note: Figures in parenthesis are t values for the corresponding data.
**, ***are significant level at 5% and 1% level respectively.

4.5.6 Comparison of Technical Efficiency (TE) Between Black Sesame and White Sesame Farmers

The mean technical efficiencies of black sesame and white sesame farmers were 0.67 and 0.66 respectively. This implied that, on average, black sesame farmers were able to obtain 67% and white sesame farmers 66% of the potential (stochastic) frontier production level in the use of given inputs and the present technology. The percent distribution of the efficiency estimates obtained from the stochastic frontier model was presented in Table 4.33. The detailed technical efficiency indices for black sesame and white sesame farmers were shown in Appendix 14 and Appendix 15 respectively and outputs from the FRONTIER (version 4.1) for black sesame farmers and white sesame farmers were indicated in Appendix 17 and Appendix 18 respectively.

For black sesame farmers, the mean technical efficiency index of black sesame farmers was 0.67 within the range of 0.11 to 1.00. About 19.04% of black sesame farmers had technical efficiency less than and equal to 0.50 (50%), 66.67% of black sesame farmers between 0.51 (51%) and 0.90 (90%), and 14.24%, more than 0.90 (90%) as shown in Table 4.33 and in Figure 4.8. The mean technical efficiency index for white sesame farmers was 0.66 within the range of 0.21 to 1.00. About 19.41% of the white sesame farmers had the technical efficiency less than and equal to 50% and 74.63% of white sesame farmers between 51% and 90% and only 5.96%, more than 0.90. Therefore, the percentage above technical efficiency 90% for black sesame farmers was higher than that of white sesame farmers indicating that black sesame farmers were more efficient in sesame production than white sesame farmers. There was no significant difference in mean technical efficiency between black sesame farmers and white sesame ones.

Percent distribution above and below mean technical efficiency for black sesame farmers and white sesame farmers was presented in Table 4.34. About 49.21% of black sesame farmers had the technical efficiency above mean technical efficiency (0.67) which means those farmers considerable efficiently operated in their farms. In the mean time, 49.21% of them had below mean technical efficiency level. It indicated that their farm operation efficiency can be increased by using the present technology. For the white sesame farmers, 44.78% of them had the technical efficiency above mean technical efficiency (0.66) which indicated that those farmers substantial proficiently operated in their farms. Moreover, 50.75% of them had technical efficiency below 0.66 which showed their production efficiency can be increased by applying the present technology.

Table 4.33 Percent distribution of farm-specific technical efficiency of black and white sesame farmers in Magway Township

Technical Efficiency Range	Black Sesame Farmers		White Sesame Farmers		All Sesame Farmers	
	Frequency	%	Frequency	%	Frequency	%
0.11-0.20	1	1.59	0	0.00	1	0.77
0.21-0.30	2	3.17	1	1.49	2	1.54
0.31-0.40	3	4.76	6	8.96	10	7.69
0.41-0.50	6	9.52	6	8.96	7	5.38
0.51-0.60	9	14.29	11	16.42	22	16.92
0.61-0.70	16	25.40	16	23.88	33	25.38
0.71-0.80	6	9.52	8	11.94	12	9.23
0.81-0.90	11	17.46	15	22.39	31	23.85
0.91-1.00	9	14.29	4	5.96	12	9.23
Total	63	100	67	100	130	100
Mean TE	0.67		0.66		0.68	
t-test	$t = -1.344^{ns}$					
Maximum TE	0.99		0.95		0.95	
Minimum TE	0.13		0.28		0.16	

Table 4.34 Percent distribution above and below average technical efficiency of black and white sesame farmers

Technical Efficiency Range	Black Sesame Farmers		Technical Efficiency Range	White Sesame Farmers	
	Frequency	%		Frequency	%
Below 0.67	31	49.21	Below 0.66	34	50.75
0.67	1	1.59	0.66	3	4.48
Above 0.67	31	49.21	Above 0.66	30	44.78
Total	63	100	Total	67	100

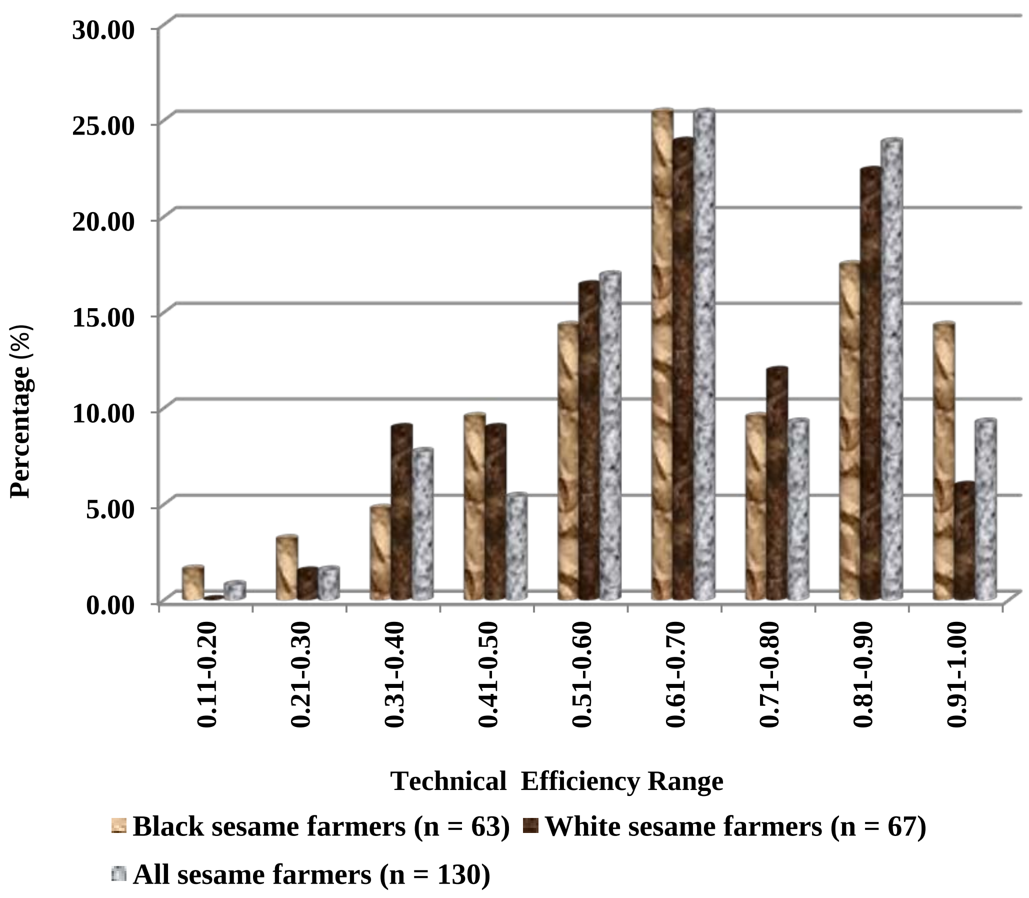


Figure 4.8 Percent distribution of farm-specific technical efficiency of black sesame farmers and white sesame farmers in Magway Township

4.6 Constraints and Problems in Sesame Production

When the farmers were asked about the constraints and problems of sesame production, they responded to the problems as indicated in Table 4.35. There were seven questions as the constraints concerning with extension contact, inadequate credit, capital requirement, infestation of pest and disease, insufficient water, poor soil and seed impurity. Among seven problems, 50.8% of the total farmers answered that they did not receive extension contact for growing sesame crop. About 36.2% of the total farmers expressed that they did not receive adequate credit and 31.5% of the total farmers expressed that they required capital investment. The problem of pest and disease, insufficient water, poor soil and seed impurity were faced by 23.1%, 14.6%, 12.3% and 5.4% of the total farmers respectively.

Table 4. 35 Constraints and problems in sesame production faced by the sample farmers

(Number of farmers)

Indicator	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
Extension contact	21 (63.6)	20 (47.6)	25 (45.5)	66 (50.8)
Pearson Chi-square		$P = 0.226^{ns}$		
Inadequate credit	11 (33.3)	24 (57.1)	12 (21.8)	47 (36.2)
Pearson Chi-square		$P = 0.001^{***}$		
Capital requirement	13 (39.4)	20 (47.6)	8 (14.5)	41 (31.5)
Pearson Chi-square		$P = 0.001^{***}$		
Infestation of pest and disease	7 (21.2)	6 (14.3)	17 (30.9)	30 (23.1)
Pearson Chi-square		$P = 0.015^{**}$		
Insufficient water	6 (18.2)	2 (4.8)	11 (20.0)	19 (14.6)
Pearson Chi-square		$P = 0.087^{ns}$		
Poor soil	5 (15.2)	7 (16.7)	4 (7.3)	16 (12.3)
Pearson Chi-square		$P = 0.320^{ns}$		
Seed Impurity	2 (6.1)	0 (0)	5 (9.1)	7 (5.4)
Pearson Chi-square		$P = 0.142^{ns}$		

Note: Figures in the parentheses represent percentage.

** and *** are significant at 1% and 5% level respectively and ns = not significant.

CHAPTER V
CONCLUSION AND POLICY IMPLICATION

5.1 Conclusion of the Study

Average education level and average farm experience of large farm household heads was the highest among three different farm size groups. Crop income was the majority of household income and also sesame income was the main source of crop income in the study area. Therefore, sesame crop was the major crop for farmers in the study area. Black sesame (*Samon*) and white sesame (*Ba Pan*) were mostly grown by the sample farm households in the study area. The use of urea fertilizer in sesame production was the highest in small farm households and the lowest in large farm households. The large farm households used the highest amount of compound fertilizer and pesticide (liquid form).

In different sample farm households, total household income was positively and significantly influenced by crop income, income from selling goods and government or company staff. Income from migration and income from others significantly influenced on total household income in medium and in large farm households.

In different sample farm households, total crop income was positively and significantly influenced by rain-fed groundnut income and rain-fed sesame income. Winter groundnut income was positively and highly significant in medium and large farm size group. Total crop income was significantly influenced by green gram income in small farm size group.

Enterprise budget was used to compare the cost and return of different sesame growing farmers. The benefit-cost ratios of sesame in small, medium and large farmers were 1.58, 1.70 and 2.05, respectively. According to the results of cost and return analysis, large farmers received more profit than small and medium farmers. The black sesame growing farmers received higher price than the white sesame growing ones. However, it was found that the yield of the white sesame was more than that of the black sesame. The benefit-cost ratio of white sesame and black sesame farmers were 1.87 and 1.76 respectively.

In factor share analysis, farm income factor share was 53.80% for all sampled farmers. The farm income factor share was 45.15% for small sampled farmers, 51.36% was for medium farmers and 59.10%, for large farmers. Among three different farm size groups, large farmers received higher factor shares for farm income than those of the medium and small farm size groups. Farm income factor share for black sesame farmers was 54.42% and that for white sesame farmers was 52.76%. Therefore, black sesame farmers received higher factor shares for farm income than that of the white sesame farmers.

Frontier efficiency has been used extensively in measuring the level of technical efficiency. The technical efficiency was measured by using FRONTIER 4.1. Yield per hectare of sesame was used as the dependent variable and seed rate, manure, urea fertilizer, human labor and animal labor were used as independent variables for production frontier. Farm size, the household head' schooling year and farmer's experience in sesame farming were explanatory variables associated with the technical inefficiency.

According to the results of production frontier analysis, the elasticity of frontier (best practice) production concerning manure (FYM) and human labor were positively and statistically influenced on sesame yield at 5% level for all sampled farmers. It can be concluded that if the farmers used FYM and human labor in sesame production, yield of sesame can be increased for all sampled farmers. All farmers in the study area overused and inefficiently used the draft animal power.

Mean technical efficiency had been found 68% among the sampled farms, which indicated that on average, the realized output can be raised by 68% without other additional resources in the study area. By proper management and proper allocation of the existing resources and technology, sufficient potential will exist for improving the productivity of sesame. Only 9.24% of all farmers had technical efficiency more than 90%.

Small, medium and large farmers could obtain 60%, 65% and 74% of mean technical efficiency, respectively of the potential (stochastic) frontier production level. The study revealed that variation in the output across agricultural farms in the study area was due to difference in their technical efficiency levels. The level of technical efficiency among agricultural households differs across farm size groups. As a result, among these three different farm size group, large farmers were more technically efficient than medium and large farmers.

The coefficient of seed rate was positively significant to black sesame yield and it indicated that black sesame farmers in the study area should use more seed in black sesame production. For inefficiency model for black sesame farmers, the negative coefficient of the household head's schooling year and the household head's experience in sesame farming indicated that educated and well-experienced farmers were more efficient in black sesame production.

The estimated coefficient for human labor was positively and statistically significant with technical efficiency of white sesame farmers. The result indicated that human labor use should be increased in white sesame production. The coefficient of farm size negatively and significantly influenced on yield of white sesame indicating that the farmers who had larger farm size were more efficient in white sesame production than the ones who had smaller farm size.

14.29% of the black sesame farmers achieved the technical efficiency above 90% and 5.96% of white sesame farmers received the technical efficiency above 90%. Therefore, black sesame farmers were slightly efficient in sesame production than white sesame farmers.

The main problems faced by most of the farmers were: reaching no technology through extension services followed by receiving inadequate credits and requiring capital investment for growing sesame crop in the study area.

5.2 Policy Implication

Good quality seed is a necessary condition for the improvement in yields for sesame production apart from other inputs like fertilizer, pesticide, etc. Hence, improved varieties of good and high yielding seeds are in demand for sesame growers. The seeds used by most farmers are those produced from their farms without selection and rejuvenation process and this has affected the quality of the crops produced and consequently, affects the income and return of the sesame farmers. Under this condition, it is urgently needed to develop seed industry through public private partnership to meet the growing demand for quality seed. The imperative needs of support of government agencies, particularly the seed division of DOA and Crop specialized technology training to both public and private sectors in registered seed production and distribution to sustain the growing needs of the agriculture industry.

Achieving a high level of technical efficiency is essential for attaining food security and profitability in farming. Present findings also show that there is a room for improvement on the level of technical efficiency in sesame production in the study area.

The development and adoption of new technology can be a key to raising the productivity of sesame farming in the study area. According to the results of frontier production function, the mean technical efficiency of small sesame farmers was low. Therefore, their biological and socio-economic constraints should be reduced. The Government's efforts to improve the technical efficiency of sesame growers should be directed more at small holders as they have higher total production costs, lower yields and net farm income, and lower technical efficiency than the medium and large growers.

Manure was a significant factor in sesame production in the study area. The sesame farmers need to use additional manure to promote yield of sesame. Therefore, compost technology should be provided to sesame farmers through training programs in order to make compost by themselves using by-products of various crops and home wastes.

In the study area, animal labor was overused in sesame production and consequently it could reduce technical efficiency of sesame farmers. Therefore, acceleration of mechanization in sesame farming should be taken into account.

As it had been found that education level is the major cause to influence technical efficiency significantly, efforts should be strengthened to promote both formal and informal education in the farming community. The production efficiency depends on the education level of farmers but it is impossible to be able to educate the farmers in a very short period of time. Hence, here, extension service, as a substitute for education, should be performed as an important and positive role.

The constraint analysis pointed out that it is effective extension services which sesame farmers in the study area are in need of. The Government should strengthen its extension service both qualitatively and quantitatively. Adequate funds should be provided for enabling the extension workers to lay out model farms and demonstration plots. In the short run, programs were designed to educate rural households through introducing farmers' training school systems and giving proper extension services. It could assist farmers to be better decision makers of their farms and it could have an impact on increasing the level of technical efficiency in sesame production.

In addition, the constraint analysis pointed out that the credit for farmers received from MADB are very low. This is necessary to improve access to credit in the study areas. The Government needs to increase and extend the rural credit programs and ensure that there is adequate credit for sesame production. In addition to INGOs and NGOs should provide the credit for sesame farmers for increasing the profitability and technical efficiency in sesame production. Credit availability can remove most of the constraints in the way of higher efficiency.

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APPENDICES

Appendix 1 Map of Magway Township

Source**:** Department of Agriculture, Township Office, Magway Township, 2011

Appendix 2 Household income from all sources by different farm size groups

(Kyat per year)

Item	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
Crop Income	287,231.06	1,067,276.79	4,489,422.73	2,317,096.15
Livestock	7,575.76	17,857.14	10,000.00	11,923.08
Selling goods	93,257.58	135,714.30	296,745.50	193,065.40
Government staff	96,363.64	81,428.57	140,272.70	110,115.40
Migration	6,060.61	200,000.00	283,636.40	186,153.80
Others	46,363.64	117,738.10	226,363.64	145,576.90
Total	536,852.29	1,620,014.90	5,446,440.97	2,963,930.73

Source: Survey data (2011)

Appendix 3 Crop income from different crops

(Kyat per year)

Crop income	Small farm households (n = 33)	Medium farm households (n = 42)	Large farm households (n = 55)	Total farm households (n = 130)
Rain-fed GN	26,231.06	236,532.74	533,670.46	308,860.58
Rain-fed SS	219,515.15	600,005.95	1,936,109.09	1,068,694.23
Winter GN	13,939.39	163,845.24	1,843,125.00	836,256.73
GG	26,333.33	56,035.71	76,658.10	77,203.85
Pigeon pea	1,212.12	10,857.14	52,627.27	26,080.77
Total	287,231.05	1,067,276.78	4,442,189.92	2,317,096.16

Source: Survey data (2011)

Appendix 4 Enterprise budget of sesame production for all sampled farmers

Item	Unit	Level	Effective Price	Total Value
1.Gross Benefit				
Yield of sesame	Kg/ha	670.32	926.59	621,111.81
Total gross benefit	Kyat/ha			**621,111.81**
2. Variable Cost				
(a) Material Cost				
Seed	Kg/ha	17.22	1,300.13	22,388.24
FYM	Ton/ha	9.60	3,600.00	34,560.00
Fertilizer(Urea)	Kg/ha	95.90	400.00	38,360.00
Fertilizer (Compound)	Kg/ha	79.01	340.00	26,863.40
Lachae fertilizer	Kg/ha	31.20	120.00	3,744.00
Pesticide 1	Liter/ha	0.47	10,000.00	4,700.00
Pesticide 2	Kg/ha	0.33	16,000.00	5,280.00
Foliar 1	Liter/ha	0.21	4,000.00	840.00
Foliar 2	Kg/ha	0.62	4,500.00	2,790.00
Total Material Cost(a)	Kyat/ha			**139,525.64**
(b)Family Labor Cost				
Plowing with machine				
Plowing with draft cattle	Amd/ha	4.03	5,000.00	20,150.00
Harrowing with draft cattle	Amd/ha	10.45	3,000.00	31,350.00
Seeding	Md/ha	0.82	1,500.00	1,230.00
Fertilizer application	Md/ha	1.75	1,000.00	1,750.00
Pesticide application	Md/ha	1.48	1,000.00	1,480.00
Manual Weeding	Md/ha	2.62	1,000.00	2,620.00
Total family labor cost(b)	Kyat/ha			**58580.00**
(c) Hired Labor Cost				
Plowing with draft cattle	Amd/ha	0.74	5,000.00	3,700.00
Harrowing with draft cattle	Amd/ha	4.22	3,000.00	12,660.00
Seeding	Md/ha	1.67	1,500.00	2,505.00
Fertilizer application	Md/ha	3.19	1,000.00	3,190.00
Pesticide application	Md/ha	5.17	1,000.00	5,170.00
Manual Weeding	Md/ha	52.78	1,000.00	52,780.00
Harvesting &Thrashing	Md/ha	39.54	1,200.00	47,448.00
Total Hired Labor Cost	Kyat/ha			**127,453.00**
(d) Interest on cash cost				
Material cost	Kyat/ha	139,525.64	0.075	10,464.42
Hired labor cost	Kyat/ha	127,453.00	0.075	9,558.98
Interest on cash cost	Kyat/ha			**20,023.40**
Return above cash cost (Gross Benefit-Total Variable Cash Cost)				**334,109.77**
Return above variable cost (Gross Benefit-Total Variable Cost)				**275,529.77**
Return per unit of cash expensed (Gross Benefit/Total Variable Cash Cost)				**2.16**
Return per unit of capital invested (Gross Benefit/Total Variable Cost)				**1.80**

Appendix 5 Enterprise budget of sesame production for small farmers (n = 33)

Item	Unit	Level	Effective Price	Total Value
1.Gross Benefit				
Yield of sesame	Kg/ha	581.31	903.89	525,440.30
Total gross benefit	Kyat/ha			**525,440.30**
2. Variable Cost				
(a) Material Cost				
Seed	Kg/ha	17.19	1,305.17	22,435.87
FYM	Ton/ha	9.45	3,600.00	34,020.00
Fertilizer(Urea)	Kg/ha	107.13	400.00	42,852.00
Fertilizer (Compound)	Kg/ha	54.25	340.00	18,445.00
Lachae fertilizer	Kg/ha	18.72	120.00	2,246.40
Pesticide 1	Liter/ha	0.32	10,000.00	3,200.00
Pesticide 2	Kg/ha	0.29	16,000.00	4,640.00
Foliar 1	Liter/ha	0.23	4,000.00	920.00
Foliar 2	Kg/ha	0.56	4,500.00	2,520.00
Total Material Cost(a)	Kyat/ha			**131,279.27**
(b)Family Labor Cost				
Plowing with draft cattle	Amd/ha	2.47	5,000.00	12,350.00
Harrowing with draft cattle	Amd/ha	7.64	3,000.00	22,920.00
Seeding	Md/ha	0.82	1,500.00	1,230.00
Fertilizer application	Md/ha	1.80	1,000.00	1,800.00
Pesticide application	Md/ha	1.95	1,000.00	1,950.00
Manual Weeding	Md/ha	3.95	1,000.00	3,950.00
Total family labor cost(b)	Kyat/ha			**44,200.00**
(c) Hired Labor Cost				
Plowing with draft cattle	Amd/ha	1.95	5,000.00	9,750.00
Harrowing with draft cattle	Amd/ha	6.74	3,000.00	20,220.00
Seeding	Md/ha	1.65	1,500.00	2,475.00
Fertilizer application	Md/ha	2.77	1,000.00	2,770.00
Pesticide application	Md/ha	3.00	1,000.00	3,000.00
Manual Weeding	Md/ha	51.14	1,000.00	51,140.00
Harvesting &Thrashing	Md/ha	39.54	1,200.00	47,448.00
Total Hired Labor Cost	Kyat/ha			**136,803.00**
(d) Interest on cash cost				
Material cost	Kyat/ha	131,279.27	0.075	9,845.95
Hired labor cost	Kyat/ha	136,803.00	0.075	10,260.23
Interest on cash cost	Kyat/ha			**20,106.17**
Return above cash cost (Gross Benefit-Total Variable Cash Cost)				**237,251.85**
Return above variable cost (Gross Benefit-Total Variable Cost)				**193,051.85**
Return per unit of cash expensed (Gross Benefit/Total Variable Cash Cost)				**1.82**
Return per unit of capital invested (Gross Benefit/Total Variable Cost)				**1.58**

Appendix 6 Enterprise budget of sesame production for medium farmers (n = 42)

Item	Unit	Level	Effective Price	Total Value
1.Gross Benefit				
Yield of sesame	Kg/ha	612.35	975.62	597,420.91
Total gross benefit	Kyat/ha			**597,420.91**
2. Variable Cost				
(a) Material Cost				
Seed	Kg/ha	16.75	1,405.82	23,547.49
FYM	Ton/ha	9.20	3,600.00	33,120.00
Fertilizer(Urea)	Kg/ha	106.39	400.00	42,556.00
Fertilizer (Compound)	Kg/ha	72.39	340.00	24,612.60
Lachae fertilizer	Kg/ha	44.36	120.00	5,323.20
Pesticide 1	Liter/ha	0.29	10,000.00	2,900.00
Pesticide 2	Kg/ha	0.41	16,000.00	6,560.00
Foliar 1	Liter/ha	0.19	4,000.00	760.00
Foliar 2	Kg/ha	0.48	4,500.00	2,160.00
Total Material Cost(a)	Kyat/ha			**141,539.29**
(b)Family Labor Cost				
Plowing with draft cattle	Amd/ha	3.12	5,000.00	15,600.00
Harrowing with draft cattle	Amd/ha	11.77	3,000.00	35,310.00
Seeding	Md/ha	1.24	1,500.00	1,860.00
Fertilizer application	Md/ha	2.59	1,000.00	2,590.00
Pesticide application	Md/ha	1.65	1,000.00	1,650.00
Manual Weeding	Md/ha	3.35	1,000.00	3,350.00
Total family labor cost(b)	Kyat/ha			**60,360.00**
(c) Hired Labor Cost				
Plowing with draft cattle	Amd/ha	0.65	5,000.00	3,250.00
Harrowing with draft cattle	Amd/ha	5.35	3,000.00	16,050.00
Seeding	Md/ha	1.24	1,500.00	1,860.00
Fertilizer application	Md/ha	2.53	1,000.00	2,530.00
Pesticide application	Md/ha	3.77	1,000.00	3,770.00
Manual Weeding	Md/ha	53.89	1,000.00	53,890.00
Harvesting &Thrashing	Md/ha	39.54	1,200.00	47,448.00
Total Hired Labor Cost	Kyat/ha			**128,798.00**
(d) Interest on cash cost				
Material cost	Kyat/ha	141539.29	0.075	10,615.45
Hired labor cost	Kyat/ha	128798.00	0.075	9,659.85
Interest on cash cost	Kyat/ha			**20,275.30**
Return above cash cost (Gross Benefit-Total Variable Cash Cost)				**306,808.33**
Return above variable cost (Gross Benefit-Total Variable Cost)				**246,448.33**
Return per unit of cash expensed (Gross Benefit/Total Variable Cash Cost)				**2.06**
Return per unit of capital invested (Gross Benefit/Total Variable Cost)				**1.70**

Appendix 7 Enterprise budget of sesame production for large farmers (n = 55)

Item	Unit	Level	Effective Price	Total Value
1.Gross Benefit				
Yield of sesame	Kg/ha	767.99	902.78	693,326.01
Total gross benefit	Kyat/ha			**693,324.21**
2. Variable Cost				
(a) Material Cost				
Seed	Kg/ha	17.60	1,216.38	21,408.29
FYM	Ton/ha	9.99	3,600.00	35,964.00
Fertilizer(Urea)	Kg/ha	81.14	400.00	32,456.00
Fertilizer (Compound)	Kg/ha	98.93	340.00	33,636.20
Lachae fertilizer	Kg/ha	28.64	120.00	3,436.80
Pesticide 1	Liter/ha	0.70	10,000.00	7,000.00
Pesticide 2	Kg/ha	0.30	16,000.00	4,800.00
Foliar 1	Liter/ha	0.20	4,000.00	800.00
Foliar 2	Kg/ha	0.76	4,500.00	3,420.00
Total Material Cost(a)	Kyat/ha			**142,921.29**
(b)Family Labor Cost				
Plowing with machine	Machine day/ha	0.18	10,000.00	1,800.00
Plowing with draft cattle	Amd/ha	3.10	5,000.00	15,500.00
Harrowing with draft cattle	Amd/ha	11.14	3,000.00	33,420.00
Seeding	Md/ha	0.49	1,500.00	735.00
Fertilizer application	Md/ha	1.08	1,000.00	1,080.00
Pesticide application	Md/ha	1.08	1,000.00	1,080.00
Manual Weeding	Md/ha	1.48	1,000.00	1,480.00
Total family labor cost(b)	Kyat/ha			**55,095.00**
(c) Hired Labor Cost				
Plowing with draft cattle	Amd/ha	0.09	5,000.00	450.00
Harrowing with draft cattle	Amd/ha	1.84	3,000.00	5,520.00
Seeding	Md/ha	2.02	1,500.00	3,030.00
Fertilizer application	Md/ha	3.95	1,000.00	3,950.00
Pesticide application	Md/ha	7.55	1,000.00	7,550.00
Manual Weeding	Md/ha	52.92	1,000.00	52,920.00
Harvesting &Thrashing	Md/ha	39.54	1,200.00	47,448.00
Total Hired Labor Cost	Kyat/ha			**120,868.00**
(d) Interest on cash cost				
Material cost	Kyat/ha	142,921.29	0.075	10,719.10
Hired labor cost	Kyat/ha	120,868.00	0.075	9,065.10
Interest on cash cost	Kyat/ha			**19,784.20**
Return above cash cost (Gross Benefit-Total Variable Cash Cost)				**409,750.72**
Return above variable cost (Gross Benefit-Total Variable Cost)				**354,655.72**
Return per unit of cash expensed (Gross Benefit/Total Variable Cash Cost)				**2.44**
Return per unit of capital invested (Gross Benefit/Total Variable Cost)				**2.05**

Appendix 8 Enterprise budget of black sesame production for all farmers (n = 63)

Item	Unit	Level	Effective Price	Total Value
1.Gross Benefit				
Yield of sesame	Kg/ha	644.53	1,017.58	655,860.84
Total gross benefit	Kyat/ha			**655,860.84**
2. Variable Cost				
(a) Material Cost				
Seed	Kg/ha	17.23	1,623.21	27,967.91
FYM	Ton/ha	8.73	3,600.00	31,428.00
Fertilizer(Urea)	Kg/ha	111.37	400.00	44,548.00
Fertilizer (Compound)	Kg/ha	69.33	340.00	23,572.20
Lachae fertilizer	Kg/ha	45.75	120.00	5,490.00
Pesticide 1	Liter/ha	0.43	10,000.00	4,300.00
Pesticide 2	Kg/ha	0.25	16,000.00	4,000.00
Foliar 1	Liter/ha	0.20	4,000.00	800.00
Foliar 2	Kg/ha	0.43	4,500.00	1,935.00
Total Material Cost(a)	Kyat/ha			**144,041.11**
(b)Family Labor Cost				
Plowing with draft cattle	Amd/ha	2.27	5,000.00	11,350.00
Harrowing with draft cattle	Amd/ha	10.86	3,000.00	32,580.00
Seeding	Md/ha	0.94	1,500.00	1,410.00
Fertilizer application	Md/ha	1.96	1,000.00	1,960.00
Pesticide application	Md/ha	1.57	1,000.00	1,570.00
Manual Weeding	Md/ha	3.14	1,000.00	3,140.00
Total family labor cost(b)	Kyat/ha			**52,010.00**
(c) Hired Labor Cost				
Plowing with draft cattle	Amd/ha	1.33	5,000.00	6,650.00
Harrowing with draft cattle	Amd/ha	5.84	3,000.00	17,520.00
Seeding	Md/ha	1.53	1,500.00	2,295.00
Fertilizer application	Md/ha	3.10	1,000.00	3,100.00
Pesticide application	Md/ha	3.96	1,000.00	3,960.00
Manual Weeding	Md/ha	53.07	1,000.00	53,070.00
Harvesting &Thrashing	Md/ha	39.54	1,200.00	47,448.00
Total Hired Labor Cost	Kyat/ha			**134,043.00**
(d) Interest on cash cost				
Material cost	Kyat/ha	144,041.11	0.075	10,803.08
Hired labor cost	Kyat/ha	134,043.00	0.075	10,053.23
Interest on cash cost	Kyat/ha			**20,856.31**
Return above cash cost (Gross Benefit-Total Variable Cash Cost)				**356,920.42**
Return above variable cost (Gross Benefit-Total Variable Cost)				**304,910.42**
Return per unit of cash expensed (Gross Benefit/Total Variable Cash Cost)				**2.19**
Return per unit of capital invested (Gross Benefit/Total Variable Cost)				**1.87**

Appendix 9 Enterprise budget of white sesame production for all farmers (n = 67)

Item	Unit	Level	Effective Price	Total Value
1.Gross Benefit				
Yield of sesame	Kg/ha	694.57	841.04	584,161.15
Total gross benefit	Kyat/ha			**584,161.15**
2. Variable Cost				
(a) Material Cost				
Seed	Kg/ha	17.22	996.33	17,156.80
FYM	Ton/ha	10.42	3,600.00	37,512.00
Fertilizer(Urea)	Kg/ha	81.35	400.00	32,540.00
Fertilizer (Compound)	Kg/ha	88.13	340.00	29,964.20
Lachae fertilizer	Kg/ha	17.52	120.00	2,102.40
Pesticide 1	Liter/ha	0.51	10,000.00	5,100.00
Pesticide 2	Kg/ha	0.41	16,000.00	6,560.00
Foliar 1	Liter/ha	0.21	4,000.00	840.00
Foliar 2	Kg/ha	0.80	4,500.00	3,600.00
Total Material Cost(a)	Kyat/ha			**135,375.40**
(b)Family Labor Cost				
Plowing with machine	Machine day/ha	0.15	10,000.00	1,500.00
Plowing with draft cattle	Amd/ha	3.58	5,000.00	17,900.00
Harrowing with draft cattle	Amd/ha	10.07	3,000.00	30,210.00
Seeding	Md/ha	0.70	1,500.00	1,050.00
Fertilizer application	Md/ha	1.55	1,000.00	1,550.00
Pesticide application	Md/ha	1.40	1,000.00	1,400.00
Manual Weeding	Md/ha	2.14	1,000.00	2,140.00
Total family labor cost(b)	Kyat/ha			**55,750.00**
(c) Hired Labor Cost				
Plowing with machine				
Plowing with draft cattle	Amd/ha	0.18	5,000.00	900.00
Harrowing with draft cattle	Amd/ha	2.69	3,000.00	8,070.00
Seeding	Md/ha	1.81	1,500.00	2,715.00
Fertilizer application	Md/ha	3.28	1,000.00	3,280.00
Pesticide application	Md/ha	6.31	1,000.00	6,310.00
Manual Weeding	Md/ha	52.52	1,000.00	52,520.00
Harvesting &Thrashing	Md/ha	39.54	1,200.00	47,448.00
Total Hired Labor Cost	Kyat/ha			**121,243.00**
(d) Interest on cash cost				
Material cost	Kyat/ha	135,375.40	0.075	10,153.16
Hired labor cost	Kyat/ha	121,943.00	0.075	9,145.73
Interest on cash cost	Kyat/ha			**19,298.88**
Return above cash cost (Gross Benefit-Total Variable Cash Cost)				**308,243.87**
Return above variable cost (Gross Benefit-Total Variable Cost)				**252,493.87**
Return per unit of cash expensed (Gross Benefit/Total Variable Cash Cost)				**2.12**
Return per unit of capital invested (Gross Benefit/Total Variable Cost)				**1.76**

Appendix 10 Technical efficiency indices of all sample farmers in the study area

Farmers' no.	TE index	Farmers' no.	TE index	Farmers' no.	TE index	Farmers' no.	TE index
1	0.87	34	0.82	67	0.53	100	0.47
2	0.83	35	0.9	68	0.85	101	0.73
3	0.65	36	0.6	69	0.32	102	0.76
4	0.88	37	0.67	70	0.7	103	0.65
5	0.81	38	0.64	71	0.51	104	0.64
6	0.54	39	0.89	72	0.35	105	0.9
7	0.87	40	0.55	73	0.55	106	0.68
8	0.87	41	0.83	74	0.43	107	0.66
9	0.87	42	0.65	75	0.66	108	0.63
10	0.95	43	0.88	76	0.28	109	0.92
11	0.4	44	0.69	77	0.41	110	0.68
12	0.92	45	0.79	78	0.87	111	0.33
13	0.72	46	0.58	79	0.57	112	0.85
14	0.91	47	0.65	80	0.66	113	0.51
15	0.81	48	0.72	81	0.65	114	0.4
16	0.93	49	0.67	82	0.67	115	0.81
17	0.81	50	0.88	83	0.45	116	0.86
18	0.93	51	0.88	84	0.8	117	0.94
19	0.89	52	0.31	85	0.51	118	0.55
20	0.64	53	0.95	86	0.93	119	0.79
21	0.75	54	0.62	87	0.68	120	0.69
22	0.88	55	0.92	88	0.55	121	0.63
23	0.91	56	0.89	89	0.32	122	0.58
24	0.84	57	0.61	90	0.85	123	0.59
25	0.81	58	0.67	91	0.54	124	0.69
26	0.9	59	0.69	92	0.16	125	0.79
27	0.53	60	0.67	93	0.43	126	0.64
28	0.55	61	0.52	94	0.34	127	0.4
29	0.92	62	0.79	95	0.38	128	0.8
30	0.76	63	0.81	96	0.27	129	0.57
31	0.89	64	0.46	97	0.7	130	0.49
32	0.65	65	0.51	98	0.58		
33	0.66	66	0.66	99	0.58		

Appendix 11 Technical efficiency indices of small sample farmers in the study area

Farmers' no.	TE index	Farmers' no.	TE index
11	0.40	87	0.68
12	0.92	89	0.32
17	0.81	92	0.16
23	0.91	95	0.38
27	0.53	104	0.64
29	0.92	106	0.68
36	0.6	107	0.66
63	0.81	108	0.63
64	0.46	109	0.92
67	0.53	111	0.33
70	0.70	113	0.51
71	0.51	115	0.81
74	0.43	117	0.94
76	0.28	126	0.64
77	0.41	127	0.40
81	0.65	128	0.80
83	0.45		

Appendix 12 Technical efficiency indices of medium sample farmers in the study area

Farmers' no.	TE index	Farmers' no	TE index
2	0.83	93	0.43
6	0.54	94	0.34
18	0.93	96	0.27
26	0.9	97	0.7
30	0.76	100	0.47
31	0.89	103	0.65
40	0.55	105	0.9
42	0.65	110	0.68
44	0.69	112	0.85
47	0.65	114	0.4
51	0.88	116	0.86
52	0.31	118	0.55
55	0.92	119	0.79
60	0.67	120	0.69
65	0.51	121	0.63
69	0.32	122	0.58
73	0.55	123	0.59
80	0.66	124	0.69
82	0.67	125	0.79
90	0.85	129	0.57
91	0.54	130	0.49

Appendix 13 Technical efficiency indices of large sample farmers in the study area

Farmers' no.	TE index	Farmers' no	TE index	Farmers' no	TE index
1	0.87	32	0.65	59	0.69
3	0.65	33	0.66	61	0.52
4	0.88	34	0.82	62	0.79
5	0.81	35	0.9	66	0.66
7	0.87	37	0.67	68	0.85
8	0.87	38	0.64	72	0.35
9	0.87	39	0.89	75	0.66
10	0.95	41	0.83	78	0.87
13	0.72	43	0.88	79	0.57
14	0.91	45	0.79	84	0.8
15	0.81	46	0.58	85	0.51
16	0.93	48	0.72	86	0.93
19	0.89	49	0.67	88	0.55
20	0.64	50	0.88	98	0.58
21	0.75	53	0.95	99	0.58
22	0.88	54	0.62	101	0.73
24	0.84	56	0.89	102	0.76
25	0.81	57	0.61		
28	0.55	58	0.67		

Appendix 14 Technical efficiency indices of black sesame farmers in the study area

Farmers' no.	TE index	Farmers' no	TE index	Farmers' no	TE index
1	0.9	79	0.67	110	0.87
2	0.86	90	0.7	111	0.43
4	0.93	91	0.56	112	0.87
6	0.55	92	0.13	113	0.44
13	0.69	93	0.37	114	0.37
16	0.99	94	0.29	115	0.83
17	0.9	95	0.31	116	0.79
19	0.84	96	0.3	117	0.96
21	0.84	97	0.71	118	0.43
23	0.97	98	0.61	119	0.62
24	0.95	99	0.73	120	0.6
25	0.91	100	0.44	121	0.54
26	0.88	101	0.63	122	0.61
30	0.7	102	0.61	123	0.53
35	0.95	103	0.65	124	0.58
41	0.81	104	0.66	125	0.7
45	0.75	105	0.82	126	0.71
48	0.56	106	0.65	127	0.46
54	0.57	107	0.64	128	0.69
56	0.91	108	0.63	129	0.57
61	0.75	109	0.99	130	0.45

Appendix 15 Technical efficiency indices of white sesame farmers in the study area

Farmers' no.	TE index	Farmers' no	TE index	Farmers' no	TE index
3	0.66	39	0.86	68	0.82
5	0.76	40	0.54	69	0.32
7	0.82	42	0.6	70	0.69
8	0.82	43	0.87	71	0.48
9	0.83	44	0.65	72	0.35
10	0.94	46	0.53	73	0.57
11	0.39	47	0.63	74	0.4
12	0.86	49	0.65	75	0.64
14	0.88	50	0.84	76	0.28
15	0.76	51	0.86	77	0.41
18	0.91	52	0.31	78	0.85
20	0.61	53	0.95	79	0.65
22	0.86	55	0.84	80	0.59
27	0.48	57	0.63	81	0.6
28	0.52	58	0.66	82	0.43
29	0.9	59	0.71	83	0.78
31	0.87	60	0.64	84	0.52
32	0.66	62	0.74	85	0.91
33	0.64	63	0.79	86	0.75
34	0.74	64	0.46	87	0.54
36	0.58	65	0.48	88	0.32
37	0.61	66	0.67		
38	0.67	67	0.54		

Appendix 16 Output from the program FRONTIER (Version 4.1) for all sample sesame farmers

```
Output from the program FRONTIER (Version 4.1c)
instruction file = god-ins.txt
data file =      god4.txt
 Tech. Eff. Effects Frontier (see B&C 1993)
 The model is a production function
 The dependent variable is logged
the ols estimates are :
              coefficient     standard-error    t-ratio

  beta 0        0.38333261E+01  0.11167577E+01  0.34325494E+01
  beta 1        0.26987901E+00  0.13385193E+00  0.20162504E+01
  beta 2        0.21560582E+00  0.88229110E-01  0.24437039E+01
  beta 3       -0.10955716E-01  0.68918413E-01 -0.15896646E+00
  beta 4        0.41819334E+00  0.21359315E+00  0.19578968E+01
  beta 5       -0.18586052E+00  0.12410897E+00 -0.14975591E+01
  sigma-squared  0.12832194E+00
log likelihood function =  -0.47931725E+02
the estimates after the grid search were :

  beta 0        0.42661158E+01
  beta 1        0.26987901E+00
  beta 2        0.21560582E+00
  beta 3       -0.10955716E-01
  beta 4        0.41819334E+00
  beta 5       -0.18586052E+00
  delta 0       0.00000000E+00
  delta 1       0.00000000E+00
  delta 2       0.00000000E+00
  delta 3       0.00000000E+00
  sigma-squared  0.30970630E+00
  gamma         0.95000000E+00

 iteration =     0  func evals =     20  llf = -0.39847146E+02
    0.42661158E+01 0.26987901E+00 0.21560582E+00-0.10955716E-01 0.41819334E+00
   -0.18586052E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
    0.30970630E+00 0.95000000E+00
 gradient step
 iteration =     5  func evals =     57  llf = -0.35155652E+02
    0.42750744E+01 0.14373156E+00 0.16956542E+00-0.46621165E-01 0.54471513E+00
   -0.19910318E+00 0.64722718E-01-0.27726293E+00-0.46338926E-01 0.20057464E-01
    0.36179017E+00 0.93916607E+00
 iteration =    10  func evals =     76  llf = -0.34420595E+02
```

0.41628278E+01 0.11149976E+00 0.15094652E+00-0.40838572E-01 0.58782595E+00
-0.18459489E+00 0.47356418E+00-0.28460065E+00 0.34639627E-01-0.67237989E-01
0.30468544E+00 0.94454454E+00
iteration = 15 func evals = 146 llf = -0.34120767E+02
0.41874905E+01 0.12093902E+00 0.15561190E+00-0.20024362E-01 0.55348608E+00
-0.17120370E+00 0.49840690E+00-0.26243233E+00-0.41847003E-02-0.35674259E-01
0.28041159E+00 0.95658860E+00
iteration = 20 func evals = 245 llf = -0.34117985E+02
0.42067569E+01 0.12435900E+00 0.15534690E+00-0.19834114E-01 0.54832306E+00
-0.17301842E+00 0.50138429E+00-0.25783690E+00-0.50274505E-02-0.37157995E-01
0.27872305E+00 0.95536265E+00
iteration = 22 func evals = 267 llf = -0.34117985E+02
0.42067425E+01 0.12436156E+00 0.15534671E+00-0.19833151E-01 0.54832602E+00
-0.17302141E+00 0.50140328E+00-0.25783352E+00-0.50347850E-02-0.37161827E-01
0.27871976E+00 0.95536247E+00

the final mle estimates are :

	coefficient	standard-error	t-ratio
beta 0	0.42067425E+01	0.11556781E+01	0.36400641E+01
beta 1	0.12436156E+00	0.12196761E+00	0.10196278E+01
beta 2	0.15534671E+00	0.70376877E-01	0.22073544E+01
beta 3	-0.19833151E-01	0.48519358E-01	-0.40876779E+00
beta 4	0.54832602E+00	0.22050790E+00	0.24866502E+01
beta 5	-0.17302141E+00	0.98484203E-01	-0.17568443E+01
delta 0	0.50140328E+00	0.41687824E+00	0.12027571E+01
delta 1	-0.25783352E+00	0.20077203E+00	-0.12842104E+01
delta 2	-0.50347850E-02	0.19086162E+00	-0.26379243E-01
delta 3	-0.37161827E-01	0.11504433E+00	-0.32302181E+00
sigma-squared	0.27871976E+00	0.16083726E+00	0.17329303E+01
gamma	0.95536247E+00	0.40830556E-01	0.23398223E+02

log likelihood function = -0.34117985E+02
LR test of the one-sided error = 0.27627480E+02
with number of restrictions = 5
[note that this statistic has a mixed chi-square distribution]
number of iterations = 22
(maximum number of iterations set at : 100)
number of cross-sections = 130
number of time periods = 1
total number of observations = 130
thus there are: 0 obsns not in the panel

covariance matrix :
0.13355920E+01 0.22686367E-02 -0.22948846E-03 -0.10124394E-01 -0.23590253E+00
-0.43134668E-01 0.20566963E+00 0.10387006E+00 0.97786459E-02 -0.59591338E-02

-0.78653321E-01 0.21736758E-01
0.22686367E-02 0.14876097E-01 -0.15467914E-03 -0.12265584E-02 -0.66528289E-02
-0.96070026E-03 0.10313499E-01 0.76203345E-02 -0.50033707E-04 0.12395521E-02
-0.63137929E-02 0.89986655E-03
-0.22948846E-03 -0.15467914E-03 0.49529049E-02 0.52843953E-03 -0.25832155E-02
0.51231091E-03 0.24229767E-02 0.30360482E-02 -0.40041486E-03 0.13110946E-02
-0.25367748E-02 0.59226761E-03
-0.10124394E-01 -0.12265584E-02 0.52843953E-03 0.23541281E-02 0.10837150E-02
-0.13929196E-02 -0.11125323E-02 -0.95647974E-03 0.18598459E-04 -0.30245068E-03
0.62936556E-03 -0.33211497E-03
-0.23590253E+00 -0.66528289E-02 -0.25832155E-02 0.10837150E-02 0.48623735E-01
0.46809079E-02 -0.43314241E-01 -0.22554520E-01 -0.41252655E-03 -0.27387392E-04
0.18294335E-01 -0.41643186E-02
-0.43134668E-01 -0.96070026E-03 0.51231091E-03 -0.13929196E-02 0.46809079E-02
0.96991383E-02 -0.19901280E-02 -0.22808787E-02 -0.23022560E-02 0.62277400E-03
0.63451531E-03 -0.55527837E-03
0.20566963E+00 0.10313499E-01 0.24229767E-02 -0.11125323E-02 -0.43314241E-01
-0.19901280E-02 0.17378747E+00 0.49770862E-01 -0.12436894E-01 -0.27454625E-01
-0.41851421E-01 0.54711874E-02
0.10387006E+00 0.76203345E-02 0.30360482E-02 -0.95647974E-03 -0.22554520E-01
-0.22808787E-02 0.49770862E-01 0.40309407E-01 -0.82257673E-02 -0.39474018E-02
-0.24087504E-01 0.34540076E-02
0.97786459E-02 -0.50033707E-04 -0.40041486E-03 0.18598459E-04 -0.41252655E-03
-0.23022560E-02 -0.12436894E-01 -0.82257673E-02 0.36428157E-01 0.41071200E-02
0.17191819E-04 0.21813977E-03
-0.59591338E-02 0.12395521E-02 0.13110946E-02 -0.30245068E-03 -0.27387392E-04
0.62277400E-03 -0.27454625E-01 -0.39474018E-02 0.41071200E-02 0.13235197E-01
-0.27447203E-02 -0.21830632E-03
-0.78653321E-01 -0.63137929E-02 -0.25367748E-02 0.62936556E-03 0.18294335E-01
0.63451531E-03 -0.41851421E-01 -0.24087504E-01 0.17191819E-04 -0.27447203E-02
0.25868623E-01 -0.10940963E-02
0.21736758E-01 0.89986655E-03 0.59226761E-03 -0.33211497E-03 -0.41643186E-02
-0.55527837E-03 0.54711874E-02 0.34540076E-02 0.21813977E-03 -0.21830632E-03
-0.10940963E-02 0.16671343E-02

Technical efficiency estimates:

firm	year	eff.-est.
1	1	0.87331453E+00
2	1	0.82584310E+00
3	1	0.64537610E+00
4	1	0.88410613E+00
5	1	0.81410154E+00
6	1	0.54279557E+00
7	1	0.87404376E+00
8	1	0.86815521E+00
9	1	0.86784814E+00
10	1	0.95121536E+00
11	1	0.40152777E+00
12	1	0.91899942E+00
13	1	0.72421065E+00
14	1	0.90925462E+00
15	1	0.81481499E+00
16	1	0.93097388E+00
17	1	0.80779674E+00
18	1	0.93219592E+00
19	1	0.89324277E+00
20	1	0.64092613E+00
21	1	0.75153376E+00
22	1	0.88193551E+00
23	1	0.90963779E+00
24	1	0.84029569E+00
25	1	0.81088917E+00
26	1	0.89746341E+00
27	1	0.52926704E+00
28	1	0.54778932E+00
29	1	0.91877335E+00
30	1	0.75581440E+00
31	1	0.89060305E+00
32	1	0.64539681E+00
33	1	0.65798276E+00
34	1	0.82000396E+00
35	1	0.90246645E+00
36	1	0.60164594E+00
37	1	0.66627472E+00
38	1	0.63828527E+00
39	1	0.88985059E+00
40	1	0.54893315E+00
41	1	0.83107287E+00
42	1	0.65217209E+00
43	1	0.88406020E+00
44	1	0.69196436E+00
45	1	0.78703693E+00
46	1	0.58217075E+00
47	1	0.64829745E+00
48	1	0.71658814E+00
49	1	0.66946509E+00
50	1	0.87612024E+00
51	1	0.88324725E+00
52	1	0.31112770E+00
53	1	0.95210503E+00
54	1	0.62370851E+00
55	1	0.92374726E+00
56	1	0.89184350E+00
57	1	0.61091765E+00
58	1	0.67119196E+00
59	1	0.69312434E+00
60	1	0.66997853E+00
61	1	0.52489530E+00
62	1	0.79112703E+00
63	1	0.81353162E+00
64	1	0.46047939E+00
65	1	0.50793408E+00
66	1	0.65641287E+00
67	1	0.53040046E+00
68	1	0.85357823E+00
69	1	0.31982263E+00
70	1	0.70303819E+00
71	1	0.50874817E+00
72	1	0.35260499E+00
73	1	0.54927580E+00
74	1	0.42717380E+00
75	1	0.66203572E+00
76	1	0.27738359E+00
77	1	0.40934019E+00
78	1	0.86894325E+00
79	1	0.57374699E+00
80	1	0.65793852E+00

81	1	0.65167478E+00	106	1	0.67649145E+00
82	1	0.66819328E+00	107	1	0.65939998E+00
83	1	0.44801005E+00	108	1	0.63143253E+00
84	1	0.79531604E+00	109	1	0.92127709E+00
85	1	0.51469672E+00	110	1	0.67809089E+00
86	1	0.92636859E+00	111	1	0.33184005E+00
87	1	0.67748730E+00	112	1	0.84844976E+00
88	1	0.54769134E+00	113	1	0.50659889E+00
89	1	0.32188853E+00	114	1	0.40251688E+00
90	1	0.85374792E+00	115	1	0.81135548E+00
91	1	0.53947630E+00	116	1	0.85796241E+00
92	1	0.16458880E+00	117	1	0.94284563E+00
93	1	0.43133724E+00	118	1	0.55087697E+00
94	1	0.33529503E+00	119	1	0.78846376E+00
95	1	0.38463180E+00	120	1	0.69473971E+00
96	1	0.27073811E+00	121	1	0.63032446E+00
97	1	0.69952227E+00	122	1	0.57662437E+00
98	1	0.57830933E+00	123	1	0.58764282E+00
99	1	0.58422689E+00	124	1	0.68554541E+00
100	1	0.47306262E+00	125	1	0.78688414E+00
101	1	0.73079760E+00	126	1	0.64137118E+00
102	1	0.76034074E+00	127	1	0.39773138E+00
103	1	0.65476581E+00	128	1	0.79581267E+00
104	1	0.63615433E+00	129	1	0.57197117E+00
105	1	0.89940511E+00	130	1	0.49342595E+00

mean efficiency = 0.67893336E+00

Appendix 17 Output from the program FRONTIER (Version 4.1) for black sesame

Output from the program FRONTIER (Version 4.1c)
instruction file = god-ins.txt
data file = dog.txt
Tech. Eff. Effects Frontier (see B&C 1993)
The model is a production function
The dependent variable is logged

the ols estimates are :
coefficient standard-error t-ratio

beta 0 0.52183432E+01 0.18883532E+01 0.27634359E+01
beta 1 0.28360863E+00 0.20536354E+00 0.13810077E+01
beta 2 0.26880396E+00 0.81380754E-01 0.33030408E+01
beta 3 0.37842762E-01 0.53293268E-01 0.71008523E+00
beta 4 0.15012809E+00 0.32066002E+00 0.46818463E+00
beta 5 -0.34932846E+00 0.19030984E+00 -0.18355774E+01
sigma-squared 0.12880364E+00

log likelihood function = -0.21682312E+02

the estimates after the grid search were :

beta 0 0.56406407E+01
beta 1 0.28360863E+00
beta 2 0.26880396E+00
beta 3 0.37842762E-01
beta 4 0.15012809E+00
beta 5 -0.34932846E+00
delta 0 0.00000000E+00
delta 1 0.00000000E+00
delta 2 0.00000000E+00
delta 3 0.00000000E+00
sigma-squared 0.29487179E+00
gamma 0.95000000E+00

iteration = 0 func evals = 20 llf = -0.17143276E+02
0.56406407E+01 0.28360863E+00 0.26880396E+00 0.37842762E-01 0.15012809E+00
-0.34932846E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.29487179E+00 0.95000000E+00
gradient step
iteration = 5 func evals = 49 llf = -0.14133202E+02
0.56490757E+01 0.11978474E-01 0.17535311E+00 0.47959652E-01 0.27778503E+00
-0.27085239E+00 0.34476233E-01-0.11553760E+00-0.11332460E+00-0.33080746E-01
0.35234994E+00 0.96568541E+00

iteration = 10 func evals = 71 llf = -0.12386745E+02
0.57431675E+01-0.52451686E-01 0.21894311E+00 0.67419597E-01 0.24976149E+00
-0.23470722E+00 0.83013926E+00-0.22849321E+00-0.22667981E+00-0.14482254E+00
0.35172062E+00 0.99155003E+00
iteration = 15 func evals = 107 llf = -0.96923380E+01
0.65615691E+01-0.18070651E+00 0.24222044E+00 0.47487953E-01 0.96836541E-01
-0.12048793E+00 0.11233553E+01-0.83090645E-01-0.30051490E+00-0.28333879E+00
0.39868822E+00 0.99999999E+00
iteration = 20 func evals = 145 llf = -0.94409477E+01
0.65240715E+01-0.18973446E+00 0.23493564E+00 0.54284159E-01 0.10646500E+00
-0.12035513E+00 0.10700571E+01-0.88836449E-01-0.28890252E+00-0.26672225E+00
0.40177145E+00 0.99999999E+00
pt better than entering pt cannot be found
iteration = 24 func evals = 175 llf = -0.94401905E+01
0.65241401E+01-0.18973419E+00 0.23493625E+00 0.54277381E-01 0.10648374E+00
-0.12040388E+00 0.10695046E+01-0.88805133E-01-0.28882706E+00-0.26658454E+00
0.40179558E+00 0.99999999E+00

the final mle estimates are :

	coefficient	standard-error	t-ratio
beta 0	0.65241401E+01	0.80717696E+00	0.80826639E+01
beta 1	-0.18973419E+00	0.10387550E+00	-0.18265539E+01
beta 2	0.23493625E+00	0.55888859E-01	0.42036329E+01
beta 3	0.54277381E-01	0.31803315E-01	0.17066580E+01
beta 4	0.10648374E+00	0.11112893E+00	0.95819994E+00
beta 5	-0.12040388E+00	0.89587817E-01	-0.13439761E+01
delta 0	0.10695046E+01	0.30893783E+00	0.34618764E+01
delta 1	-0.88805133E-01	0.21263740E+00	-0.41763646E+00
delta 2	-0.28882706E+00	0.16330765E+00	-0.17686070E+01
delta 3	-0.26658454E+00	0.12179096E+00	-0.21888697E+01
sigma-squared	0.40179558E+00	0.12298935E+00	0.32669135E+01
gamma	0.99999999E+00	0.15872864E-05	0.63000603E+06

log likelihood function = -0.94401905E+01

LR test of the one-sided error = 0.24484244E+02
with number of restrictions = 5
[note that this statistic has a mixed chi-square distribution]
number of iterations = 24
(maximum number of iterations set at : 100)
number of cross-sections = 63
number of time periods = 1
total number of observations = 63

thus there are: 0 obsns not in the panel

covariance matrix :
0.65153465E+00 -0.63020040E-01 -0.18445498E-01 0.69314927E-02 -0.82305173E-01
-0.27663087E-01 0.14298711E+00 -0.20300576E-01 -0.16765808E-01 -0.43016298E-01
0.33300871E-02 -0.18735521E-06
-0.63020040E-01 0.10790119E-01 -0.13243025E-02 -0.14600640E-03 0.72195238E-02
0.82364900E-03 0.24852694E-02 0.12317462E-02 0.86184830E-03 0.12987745E-04
-0.13623895E-02 0.58409716E-08
-0.18445498E-01 -0.13243025E-02 0.31235645E-02 0.16280734E-03 0.21240543E-02
0.16808482E-02 -0.53558215E-02 0.20392772E-02 0.29912099E-04 0.10301807E-02
-0.35785909E-03 0.17868159E-09
0.69314927E-02 -0.14600640E-03 0.16280734E-03 0.10114508E-02 -0.10134559E-02
-0.22853964E-02 -0.25476759E-02 0.81307134E-04 0.11854104E-02 0.14360944E-04
0.17604420E-03 0.53727600E-08
-0.82305173E-01 0.72195238E-02 0.21240543E-02 -0.10134559E-02 0.12349639E-01
0.16221292E-02 -0.12047381E-01 0.18257660E-02 0.14010910E-02 0.34551696E-02
0.53613021E-04 -0.11387064E-07
-0.27663087E-01 0.82364900E-03 0.16808482E-02 -0.22853964E-02 0.16221292E-02
0.80259769E-02 -0.26916477E-01 0.13452399E-02 0.12416604E-02 0.90591013E-02
0.21182505E-03 0.76138205E-07
0.14298711E+00 0.24852694E-02 -0.53558215E-02 -0.25476759E-02 -0.12047381E-01
-0.26916477E-01 0.95442580E-01 0.33676126E-01 -0.25872663E-01 -0.14004658E-01
-0.55087735E-02 0.53626770E-06
-0.20300576E-01 0.12317462E-02 0.20392772E-02 0.81307134E-04 0.18257660E-02
0.13452399E-02 0.33676126E-01 0.45214665E-01 -0.86236789E-02 -0.24655903E-01
-0.40305301E-02 -0.68738823E-07
-0.16765808E-01 0.86184830E-03 0.29912099E-04 0.11854104E-02 0.14010910E-02
0.12416604E-02 -0.25872663E-01 -0.86236789E-02 0.26669389E-01 0.15631031E-02
-0.66618809E-02 -0.83104122E-07
-0.43016298E-01 0.12987745E-04 0.10301807E-02 0.14360944E-04 0.34551696E-02
0.90591013E-02 -0.14004658E-01 -0.24655903E-01 0.15631031E-02 0.14833039E-01
-0.41830810E-02 -0.12743387E-06
0.33300871E-02 -0.13623895E-02 -0.35785909E-03 0.17604420E-03 0.53613021E-04
0.21182505E-03 -0.55087735E-02 -0.40305301E-02 -0.66618809E-02 -0.41830810E-02
0.15126381E-01 -0.83429271E-08
-0.18735521E-06 0.58409716E-08 0.17868159E-09 0.53727600E-08 -0.11387064E-07
0.76138205E-07 0.53626770E-06 -0.68738823E-07 -0.83104122E-07 -0.12743387E-06
-0.83429271E-08 0.25194781E-11

technical efficiency estimates :

firm	year	eff.-est.
1	1	0.89567143E+00
2	1	0.86474645E+00
3	1	0.92813719E+00
4	1	0.54643637E+00
5	1	0.68808893E+00
6	1	0.99982449E+00
7	1	0.90310674E+00
8	1	0.83800518E+00
9	1	0.84191549E+00
10	1	0.96988226E+00
11	1	0.95398035E+00
12	1	0.91044897E+00
13	1	0.88055518E+00
14	1	0.69884636E+00
15	1	0.95113607E+00
16	1	0.80979076E+00
17	1	0.74731575E+00
18	1	0.56343829E+00
19	1	0.57019494E+00
20	1	0.91356378E+00
21	1	0.75250427E+00
22	1	0.66908347E+00
23	1	0.69924181E+00
24	1	0.55850885E+00
25	1	0.12902366E+00
26	1	0.36938247E+00
27	1	0.28999579E+00
28	1	0.31410860E+00
29	1	0.30249114E+00
30	1	0.70835082E+00
31	1	0.60647599E+00
32	1	0.73427966E+00
33	1	0.44024579E+00
34	1	0.62917522E+00
35	1	0.61091316E+00
36	1	0.65130916E+00
37	1	0.66326770E+00
38	1	0.81749216E+00
39	1	0.64670255E+00
40	1	0.64496143E+00
41	1	0.62621502E+00
42	1	0.98937991E+00
43	1	0.87166613E+00
44	1	0.42857180E+00
45	1	0.86978102E+00
46	1	0.43706847E+00
47	1	0.36953628E+00
48	1	0.82894239E+00
49	1	0.79126185E+00
50	1	0.96489875E+00
51	1	0.43344119E+00
52	1	0.61659975E+00
53	1	0.59563649E+00
54	1	0.54316049E+00
55	1	0.61312082E+00
56	1	0.52771797E+00
57	1	0.57724820E+00
58	1	0.70472049E+00
59	1	0.71069653E+00
60	1	0.45878532E+00
61	1	0.69398954E+00
62	1	0.56757839E+00
63	1	0.44861992E+00

mean efficiency = 0.67271802E+00

Appendix 18 Output from the program FRONTIER (Version 4.1) for white sesame

Output from the program FRONTIER (Version 4.1c)
instruction file = god-ins.txt
data file = dog1.txt
Tech. Eff. Effects Frontier (see B&C 1993)
The model is a production function
The dependent variable is logged
the ols estimates are :

	coefficient	standard-error	t-ratio
beta 0	0.29917335E+01	0.14176181E+01	0.21103945E+01
beta 1	0.27095281E+00	0.17634812E+00	0.15364656E+01
beta 2	0.14743344E-01	0.11596941E+00	0.12713132E+00
beta 3	0.80913913E-02	0.29160954E-01	0.27747347E+00
beta 4	0.62538997E+00	0.30704389E+00	0.20368097E+01
beta 5	-0.95629201E-01	0.19145154E+00	-0.49949560E+00
sigma-squared	0.12608639E+00		

log likelihood function = -0.22554554E+02

the estimates after the grid search were :

beta 0	0.33692408E+01
beta 1	0.27095281E+00
beta 2	0.14743344E-01
beta 3	0.80913913E-02
beta 4	0.62538997E+00
beta 5	-0.95629201E-01
delta 0	0.00000000E+00
delta 1	0.00000000E+00
delta 2	0.00000000E+00
delta 3	0.00000000E+00
sigma-squared	0.25730684E+00
gamma	0.87000000E+00

iteration = 0 func evals = 20 llf = -0.20287974E+02
0.33692408E+01 0.27095281E+00 0.14743344E-01 0.80913913E-02 0.62538997E+00
-0.95629201E-01 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.25730684E+00 0.87000000E+00
gradient step
iteration = 5 func evals = 49 llf = -0.15112469E+02
0.33712564E+01 0.22867211E+00 0.39792278E-01-0.21364285E-02 0.68890675E+00
-0.16405298E+00 0.50646215E-01-0.41538340E+00 0.23601894E+00-0.17035165E-01
0.30510973E+00 0.91257903E+00
iteration = 10 func evals = 69 llf = -0.14142922E+02
0.32100032E+01 0.14730351E+00 0.23559466E-01-0.30894217E-02 0.76036772E+00
-0.13273700E+00 0.33987154E+00-0.38116614E+00 0.36245821E+00-0.13481360E+00
0.20046128E+00 0.85237677E+00
iteration = 15 func evals = 140 llf = -0.13758739E+02
0.31288216E+01 0.15170384E+00 0.34468747E-01-0.34363931E-02 0.77660080E+00
-0.12487948E+00 0.52447671E+00-0.24661126E+00 0.21631658E+00-0.96888527E-01
0.15537989E+00 0.86246293E+00
iteration = 20 func evals = 244 llf = -0.13704870E+02
0.35073049E+01 0.12085163E+00 0.45173905E-01-0.18044084E-02 0.72359469E+00
-0.13898448E+00 0.60921343E+00-0.23283476E+00 0.19758924E+00-0.10140196E+00
0.15045354E+00 0.89722397E+00
iteration = 25 func evals = 340 llf = -0.13703496E+02
0.34607988E+01 0.11761378E+00 0.46792823E-01-0.18102974E-02 0.73492234E+00
-0.13922340E+00 0.61178601E+00-0.23488334E+00 0.19787203E+00-0.10152446E+00
0.15137300E+00 0.89890498E+00
pt better than entering pt cannot be found
iteration = 27 func evals = 368 llf = -0.13703496E+02
0.34608108E+01 0.11761709E+00 0.46792367E-01-0.18107847E-02 0.73491931E+00
-0.13922288E+00 0.61178909E+00-0.23488126E+00 0.19787271E+00-0.10152231E+00
0.15137018E+00 0.89890503E+00

the final mle estimates are :

	coefficient	standard-error	t-ratio
beta 0	0.34608108E+01	0.13843649E+01	0.24999267E+01
beta 1	0.11761709E+00	0.16503335E+00	0.71268681E+00
beta 2	0.46792367E-01	0.10632024E+00	0.44010780E+00
beta 3	-0.18107847E-02	0.27172358E-01	-0.66640692E-01
beta 4	0.73491931E+00	0.28128180E+00	0.26127510E+01
beta 5	-0.13922288E+00	0.17320856E+00	-0.80378751E+00
delta 0	0.61178909E+00	0.42903874E+00	0.14259530E+01
delta 1	-0.23488126E+00	0.11598901E+00	-0.20250304E+01
delta 2	0.19787271E+00	0.14435293E+00	0.13707565E+01
delta 3	-0.10152231E+00	0.10002558E+00	-0.10149635E+01
sigma-squared	0.15137018E+00	0.59997465E-01	0.25229429E+01
gamma	0.89890503E+00	0.15250619E+00	0.58942199E+01

log likelihood function = -0.13703496E+02
LR test of the one-sided error = 0.17702117E+02
with number of restrictions = 5
[note that this statistic has a mixed chi-square distribution]
number of iterations = 27
(maximum number of iterations set at : 100)
number of cross-sections = 67
number of time periods = 1
total number of observations = 67
thus there are: 0 obsns not in the panel
covariance matrix :

0.19164662E+01 -0.35074290E-01 0.36491011E-02 0.66035451E-03 -0.33675915E+00
-0.63211712E-01 0.15198468E+00 0.47953558E-01 -0.43831193E-01 0.77500475E-02
-0.23087082E-01 0.45124633E-01
-0.35074290E-01 0.27236008E-01 -0.56228936E-02 -0.38059578E-03 -0.89606143E-02
0.23480423E-02 -0.11250086E-01 -0.17919348E-02 0.28217213E-02 -0.10849415E-02
-0.17030017E-03 -0.10933722E-01
0.36491011E-02 -0.56228936E-02 0.11303994E-01 0.10840480E-02 0.14820235E-03
-0.41807175E-02 0.14197525E-01 0.33103276E-02 -0.43257095E-02 -0.11031183E-03
0.36030800E-04 0.95352247E-02
0.66035451E-03 -0.38059578E-03 0.10840480E-02 0.73833702E-03 -0.53432969E-03
-0.72270825E-03 0.20419436E-02 0.38703015E-03 -0.83792875E-03 -0.22597449E-03
0.17605854E-03 0.10523080E-02
-0.33675915E+00 -0.89606143E-02 0.14820235E-03 -0.53432969E-03 0.79119453E-01
-0.47685414E-02 -0.17045711E-01 -0.59274934E-02 0.58074718E-02 -0.16205344E-02
0.46752955E-02 0.24902337E-02
-0.63211712E-01 0.23480423E-02 -0.41807175E-02 -0.72270825E-03 -0.47685414E-02
0.30001206E-01 -0.17284323E-01 -0.51579766E-02 0.45365625E-02 0.18250487E-02
-0.69879897E-03 -0.13184553E-01
0.15198468E+00 -0.11250086E-01 0.14197525E-01 0.20419436E-02 -0.17045711E-01
-0.17284323E-01 0.18407424E+00 0.21770768E-01 -0.41279843E-01 -0.21950005E-01
-0.82773743E-02 0.24395912E-01
0.47953558E-01 -0.17919348E-02 0.33103276E-02 0.38703015E-03 -0.59274934E-02
-0.51579766E-02 0.21770768E-01 0.13453450E-01 -0.94840905E-02 0.89790495E-04
-0.39375147E-02 0.55464027E-02
-0.43831193E-01 0.28217213E-02 -0.43257095E-02 -0.83792875E-03 0.58074718E-02
0.45365625E-02 -0.41279843E-01 -0.94840905E-02 0.20837767E-01 -0.23000074E-02
0.36455685E-02 -0.52786726E-02
0.77500475E-02 -0.10849415E-02 -0.11031183E-03 -0.22597449E-03 -0.16205344E-02
0.18250487E-02 -0.21950005E-01 0.89790495E-04 -0.23000074E-02 0.10005117E-01
-0.12738677E-02 -0.10008802E-02
-0.23087082E-01 -0.17030017E-03 0.36030800E-04 0.17605854E-03 0.46752955E-02
-0.69879897E-03 -0.82773743E-02 -0.39375147E-02 0.36455685E-02 -0.12738677E-02
0.35996958E-02 0.15335959E-02

0.45124633E-01 -0.10933722E-01 0.95352247E-02 0.10523080E-02 0.24902337E-02
-0.13184553E-01 0.24395912E-01 0.55464027E-02 -0.52786726E-02 -0.10008802E-02
0.15335959E-02 0.23258139E-01

technical efficiency estimates :

firm	year	eff.-est.
1	1	0.66166025E+00
2	1	0.75795616E+00
3	1	0.82391232E+00
4	1	0.82442142E+00
5	1	0.82617606E+00
6	1	0.93742519E+00
7	1	0.39149217E+00
8	1	0.85812885E+00
9	1	0.87691100E+00
10	1	0.76266772E+00
11	1	0.90666365E+00
12	1	0.61354527E+00
13	1	0.86159291E+00
14	1	0.47820593E+00
15	1	0.51725767E+00
16	1	0.89644591E+00
17	1	0.86565590E+00
18	1	0.65881209E+00
19	1	0.64079981E+00
20	1	0.74412502E+00
21	1	0.57943079E+00
22	1	0.60935648E+00
23	1	0.66625705E+00
24	1	0.86477811E+00
25	1	0.54381767E+00
26	1	0.60497916E+00
27	1	0.86802671E+00
28	1	0.65146787E+00
29	1	0.53105517E+00
30	1	0.62869850E+00
31	1	0.65383712E+00
32	1	0.83672046E+00
33	1	0.86239281E+00
34	1	0.31421968E+00
35	1	0.94686564E+00
36	1	0.83952893E+00
37	1	0.62972023E+00
38	1	0.65755716E+00
39	1	0.70608019E+00
40	1	0.64192833E+00
41	1	0.73709971E+00
42	1	0.79152317E+00
43	1	0.46167156E+00
44	1	0.47690544E+00
45	1	0.67020148E+00
46	1	0.53603771E+00
47	1	0.82361781E+00
48	1	0.32247235E+00
49	1	0.69468067E+00
50	1	0.48164409E+00

51	1	0.35233988E+00
52	1	0.56545577E+00
53	1	0.39999062E+00
54	1	0.63657923E+00
55	1	0.27724794E+00
56	1	0.40565068E+00
57	1	0.84760947E+00
58	1	0.64807128E+00
59	1	0.59245225E+00
60	1	0.60242021E+00
61	1	0.43369834E+00
62	1	0.78343279E+00
63	1	0.51796960E+00
64	1	0.90989304E+00
65	1	0.74931358E+00
66	1	0.53518554E+00
67	1	0.32009640E+00

mean efficiency = 0.65841543E+00