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Technical Efficiency of Red Chili Pepper (*Capsicum annum L.*) Farming in Bangli, Indonesia

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Abstract. The trend of production input usage on Demand for Red chili pepper (*Capsicum annuum* L.) is increasing and a corresponding increase in production needs to be driven by increased efficiency. The aim of this research was to analyse the technical efficiency of red pepper farming, in Bangli District, Bali, Indonesia. Primary data was obtained by interviewing 60 farmers who were selected by random sampling and by using structured questionnaires. Secondary data was collected through literature study. *Maximum Likelihood Estimator* (MLE) was employed to analyse the data by estimating the stochastic production frontier model. The results of the study showed that (1) increased land size, good quality seed, correct application of KCL, NPK fertilizer, chicken manure, correct application of pesticides and the amount of labour used will be effective in increasing Red chili pepper production. In contrast incorrect fertilizer and pesticide application has the potential to decrease production; (2) Red chili pepper farming had historically been conducted efficiently but is now below optimum; (3) A properly trained and educated workforce will increase Red chili pepper production.

1. INTRODUSTION

Red chili pepper (*Capsicum annuum* L.) is a high economic value crop. Annual demand for this crop is increasing in line with population growth in Indonesia of around 1.1 % per year and is also increasing as the food industry develops additional offerings to the consumer [1]. However, production is currently below optimum levels. Average annual production from 2012 to 2015 was 1.02 Million Tons from a cultivated area of 123,500 hectares giving a yield of 8.26 tons per hectare [2] compared to a potential yield up to 20 tons per [3]. Efforts to improve yields have been made using the introduction of a new variety of Red Chill Pepper, development and introduction of improved cultivation techniques along with the introduction of a number of technological innovations.

The Kintamani area is one of the major red chili pepper producing areas in Bali, Indonesia. In order to improve productivity consideration needs to be given to the farmer willingness and ability to follow the input they are given to enable them to improve yields and quality of crops. Typically, the farmers prefer to apply dosages of fertilizers and pesticides that are different than those recommended in the belief that the recommended amounts are ineffective and inefficient and so do not provide maximum benefits. In general, farmers use synthetic pesticides intensively and at higher doses than recommended. This is consistent with previous research was conducted by Sutardi and Wirasti [4] in Yogyakarta indicate that farmers use chemical pesticides intensively with high doses. Regarding fertilizer use, farmers in Kintamani use N fertilizer at an average of 50 kg / ha, P fertilizer at an

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average of 50 kg / ha and K fertilizer at an average of 72.5 kg / ha for red chili pepper. According to Soetiarso et al [5], the use of N, P and K fertilizers is 150 kg / ha, respectively, efficient for red chili pepper.

Production efficiency is largely determined by the type and number of inputs adopted by the farmers and their ability to properly manage their farming operations as well as other factors beyond their control such as the weather which can greatly impact crop yields. This paper aims to analyze the technical efficiency of Red Chili Pepper farming in Bangli Regency, Kintamani, Bali, Indonesia.

2. RESEARCH METHODOLOGY

This research was conducted in Songan B Village, Kintamani District, Bali, Indonesia. It involved gathering responses from 60 farmers who were randomly selected from five groups of crop farmers in the Village totaling 125 members. The data gathered was both quantitative and qualitative and was sourced from the responses of farmers engaged in Red Chili Pepper farming during the planting season of March and April 2016. Primary data included plant density, type, number and quantities of production inputs used, man hours worked, crop yield and other related data. The data was collected by use of a structured questionnaire containing both open and closed questions. The secondary data was gathered from a study of related literature from various institutions. Analysis of technical efficiency carried out during this research was conducted using *Stochastic Frontier Production Function* in conjunction with *Maximum Likelihood Estimator* (MLE).

The MLE estimation for the Cobb Douglas production function parameters and the technical inefficiency model are performed simultaneously using the Frontier 4.1 Program computer package from [6]. Production function describes technical relation between the inputs used and the output obtained. The production of Red Chili Peppers in this research was estimated to be dependent on 8 separate variables: increased land size, good quality seed, correct application of KCL, NPK fertilizer, chicken manure, correct application of pesticides and the amount of labour used. Estimation of the effect of independent variables on the red chili pepper production was done using the Cobb Douglas production function model with the Stochastic Production Frontier approach, as follows:

$$LnY = \ln\beta_0 + \beta_1\ln X_1 + \beta_2\ln X_2 + \beta_3\ln X_3 + \beta_4\ln X_4 + \beta_5\ln X_5 + \beta_6\ln X_6 + \beta_7\ln X_7 + \beta_8\ln X_8 + (vi - ui)$$

where, Y = red chili pepper production (ton); β_0 = intercept; β_i = regression coefficient (i = 1 s.d 8); X_1 = population of red chili pepper (ph); X_2 = quantity of KCl (kg); X_3 = quantity of NPK (15:15:15) (kg); X_4 = quantity of ZA (kg); X_5 = quantity of chicken manure (kg); X_6 = quantity of insecticide (ml, gr); X_7 = quantity of fungicide (kg, lt); X_8 = quantity of labor (One Working Day/8 hours); vi– ui = *error term* (ui) effect of technical inefficiency.

Technical efficiency was analyzed using the following formula:

$$TE_i = \frac{E(YU_i,X_i)}{E(Y^*\neq 0,X_i)} = E[\exp(-U_i)/\varepsilon_i],$$

where, TE_i = technical efficiency of farmer-i; $E[\exp(-u_i)/\varepsilon_i]$ = expected value (*mean*) from u_i with the requirement ε_i.; TE value between 0 and 1 ($0<TE\leq1$).

The technical efficiency value is conversely related to the inefficiency effect value and is only being used in the conjunction with the function that have *cross section data*. The technical efficiency method used in this study refers to the technical inefficiency model developed by [6]. These three influencing factors are the potential sources of inefficiency to be examined in this study, i.e. Age, level of formal education, and years of farming experience of the farmers engaged in red chili pepper farming. The determination of the distribution value parameter (μ_i) of the technical inefficiency effect is stated as follows:

$$(\mu i) = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3$$

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where, μ_i = effect of technical efficiency; δ_0 = intercept; δ_{1-3} = regression coefficient; Z_1= farmers'age (year); Z_2=level of formal education (year); Z_3 = farming experience (year)

3. RESULT AND DISCUSSION

3.1 Respondent characteristics

Data gathered from the respondents to the questionnaire used in this study consisted of the respondents age, level of formal education achieved, or the time spent in formal education and the number of years of experience they had of farming Red Chili Peppers. Analysis of the respondent questionnaires showed that the average age of respondents was 39.25 years, ranging from 27 to 61 years. Most farmers (93.33%) were of productive age, only 6.67% were of non-productive age or old age. The data collected indicated that potential for improvement of Red Chili Pepper farming in the area exists.

Related to the education of respondents, according to the data gathered from the questionnaires 50% of the respondents were educated to Elementary School level, 28.33% were educated to Junior High School level, 18.33% were educated to Senior High School level and only 3.33% were educated to College Degree level. This indicates that the educational level of the majority of respondents was relatively low which has impacted their ability to accept innovation and lessened their farm management skills.

Experience of Red Chili Pepper farming is defined as the total number of years a farmer has spent cultivating this crop. Data gathered from the questionnaires showed that the average number of years spent cultivating Red Chili Peppers was 17.92 years ranging from 5 years to 40 years of individual experience. A majority of the respondents (80%) had more than 10 years of experience while only 20% of the respondents had farmed for between 5 and 9 years.

3.2 Performance of red chili pepper farming

The farmers used two varieties of seedlings – *Hot Chili* and *Pilar* – both of which are well suited to be grown in the highlands of Kintamani and have a potential yield of $\pm$ 30 ton/ha and $\pm$ 22 ton/ha respectively. The selection of Red Chili Pepper variety to be used is important as it affects production [3], [7], [8]. Red Chili pepper cultivation in the planting season of March/April 2016 was done by using a crop rotation system in conjunction with shallot bulbs. Red Chili pepper was planted 35 to 40 days after the shallot bulbs had been planted. This protected the young Red Chili Pepper seedlings from direct sunlight [9]. In addition, the other purpose of the crop rotation is for land use efficiency and to avoid soil nutrient competition since, when the chili plants begin to require high nutrients for growth and development, when the shallot is around 65-70 days after planting (DAP), the shallots have been harvested already [10]

Based on data for the plot being studied the cultivated area was 0.21 hectares and the plant population was 4,084 plants. The Red Chili Peppers were planted on the side of the raised beds where the shallot bulbs were planted. Spacing between the Red Chili Pepper plants was 50 cms x 70 cms and each bed had two rows, in accordance with [11]. The height of bed was about 25 cm from the ground, width 1.2 m, and its length depended on the land topography. The beds had been given chicken manure as a basic fertilizer before planting shallots. The amount of chicken manure used was an average of 14.15 t / ha. Chicken manure had been used by farmers in the area for many years. The chicken manure is the best organic fertilizer for Red Chili Peppers [12] and the dose recommendation is 30 ton/ ha [13]. Therefore, compared to the recommended dose, the application of chicken manure in this case was very low.

The Red Chili Pepper plants were watered once a day either in the morning or afternoon while they were growing due to the high porosity of the soil and the remaining which is a mix of clay and sand and is quite porous. Weeding was carried out 3 or 4 times during the growing period. The first weeding was done the day after the shallots were harvested and the remaining weeding was done 45, 60 and 75 (DAP).

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Application of fertilizer was done using NPK, ZA and KCL. Application of NPK and ZA was carried out weekly starting at 14 DAP and continuing until 70 DAP. Once the chili plants started to flower the weekly application of NPK was augmented with the addition of ZA and KCL until the end of harvesting. As can be seen in Table 1 the average amount of NPK fertilizer applied to the Red Chili Plants was 333.85 Kg per Ha, KCL was 49.94 Kg per Ha and ZA was 98.36 Kg per Ha. Based on the quantities of NPK, ZA and KCL detailed in the previous paragraph it can be calculated that 70.73 Kg per Ha of N element, 72.35 Kg per Ha of K_2O and 50.08 Kg per Ha of P_2O_5 were applied to the Red Chili Pepper plants. While, according to [5] that the impact of fertilizer application on the production results of Red Chili Peppers can be quite high when applied in the ratio of 150 Kg/ Ha of N, P_2O_5, and K_2O. Setiawati et al. [11] recommend applying N at 132 Kg per Ha from urea and ZA fertilizer; applying K_2O at 67.5 Kg per Ha from KCl fertilizer and P_2O_5 at 54 Kg / Ha from TSP fertilizer. Moekasan et al. [9] stated that the total of elements N, K_2O, and P_2O_5 given to the Red Chili Pepper plants is 71.5 kg/ha. These recommendations indicated that quantities of fertilizer recommended are depending on location specific conditions.

Table 1. Production input in the red chili pepper farming in March/ April 2016 planting season in Kintamani, Bangli, Bali, Indonesia

Production input	Quantity	
	Per farm (0.21 ha)	Per hectare
Seedling	4,083.75	19,090.38
Plastic mulch (roll)	2.67	12.50
KCl fertilizer (kg)	10.68	49.94
NPK (15:15:15) (kg)	71.42	333.85
ZA fertilizer (kg)	21.04	98.36
Chicken manure (ton)	3,027.50	14,152.71
Insecticide (ml, gr)	1,581.67	7,393.84
Fungicide (gr, ml)	3,981.63	18,613.01
Labor (1 working day = 8 hrs)	87.84	410.62

Pests and diseases which attack Red Chili Peppers are varied in type and nature. To combat the pest problem the farmers use synthetic pesticide intensively. In particular it had is applied every week at a higher dose that that recommended by the manufacturer. Most farmers apply between 2 and 5 types of synthetic pesticides mixed together without considering what effect doing this will have. The higher the number of pests seen attacking the Red Chili Pepper plants the shorter the interval is between pesticides spraying. This mirrors the findings of [14].

The first harvest is done when the Red Chili Pepper plants reach 115 – 120 DAP. Harvesting was done weekly and the total number of harvests was 9 to 16. The highest yield was obtained in the 5th or 6th harvest. The total Red Chili Peppers harvested averaged 12.77 Tons per Ha or 0.66 Kg per plant. This yield is much lower than the potential harvest [3] but it is higher than the national average productivity of 8.65 Tons per Ha [2]

3.3 The stochastic frontier production function analysis

The stochastic frontier production function and the technical inefficiency models are jointly estimated by the maximum-likelihood method. The result shows that seven out of nine independent variable models indicate positive effects, with six out of the eight significantly affecting production, while one variable model had no effect at all. KCl fertilizer significantly affects the production of red chili pepper yet the coefficient is lower than the area of land and seeds (Table 2).

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Tabel 2. The results of estimating production function of red chili pepper farming in March / April 2016 planting season in Kintamani, Bangli, Bali, Indonesia

Variables	Parameter	Coefficient	*Standard error*	t-rasio
Constant	β_0	2.249	0.488	4.608**
Area (ha)	β_1	0.562	0.195	2.877*
Seedling (plant)	β_2	0.421	0.185	2.278**
KCl (kg)	β_3	0.207	0.346	5.977**
NPK(kg)	β_4	0.100	0.439	2.284*
ZA (kg)	β_5	0.054	0.033	1.638 ^{ns}
Chicken manure (kg)	B_6	0.036	0.014	2.536*
Insecticide (ml, gr)	B_7	-0.120	0.041	-2.935**
Fungicide (gr, ml)	B_8	-0.158	0.030	-5.329**
Labour (8 hours)	B_9	0.152	0.074	2.049*

Note: * = significance 5% ; ** = significance 1%; ns = non significant

Land area shows the highest coefficient among other independent variable, as much as 0.562 with a significant effect on the level of 1%. This coefficient means that an increase in planting area of one percent (*ceteris paribus*) will increase red chili yield by 0.56 percent. The coefficient of each of these variables also reflects its elasticity on the production of red chili pepper. All inputs used are inelastic towards the production of the red chili peppers, which is shown by the coefficient <1. This means that the addition of a certain input of 1 percent is only able to increase production <1 percent. Land area demonstrates the highest elasticity amongst all the variables in the Model meaning that alteration of the land area under cultivation has the most significant effect on Red Chili Pepper production. Agricultural land under cultivation is the most influential factor in determining production and its area must be preserved in order to sustain production of agricultural products, in this case Red Chili Peppers, at a high enough level to meet demand.

Table 2 illustrates that there are two variables which negatively affect Red Chili Pepper production, namely insecticide and fungicide. This reflects the fact that the use of pesticides at the farmers' location has reduced the production of red chili pepper. The data also indicates that farmers at the research site use higher amounts of pesticides than the recommended dosage (Table 1). Inappropriate use of synthetic pesticides leads to multidimensional negative impacts, one of which is killing natural enemies of the pests and microorganisms in the soil that are beneficial for maintaining soil fertility. This causes the natural quality of the land to be degraded and agricultural production will decrease.

Basically, the farmers understand the negative impact of using excessive amounts of synthetic pesticides, however, they lack information on alternative methods which can be used to control pest and disease infection. Several studies have been done on how to reduce the use of synthetic pesticides. Integrated pest management techniques can be applied to reduce synthetic pesticide application and increase the Red Chili Pepper production [12]; [15]. Moreover, some studies on the usage of natural materials as biopesticide has been freely available too [16]; [17]; [18]. Prabaningrum and Moekasan [19] recommended the use of screen house and plastic mulch to control red chili pepper pests and diseases in highland locations.

The findings of these research studies should be socialized to the farmers, particularly the younger ones, as quickly as possible and the farmers assisted in implementing the recommendations. However, first it is necessary to evaluate each component of the recommendations and determine which are the most practical to be implemented while delivering the greatest benefits after discussions with the farmers themselves. In general the farmers will choose the most practical innovations that match their needs, are easy to apply, affordable, utilize locally available materials and, perhaps most importantly, show significant financial benefits for them.

The value of production coefficient function is the *return to scale* condition, where the result is 1.254. This value means, if all the input were added altogether of 10 % will increase the yield of red chili pepper for 12.54 %. This value reflects the Cobb Douglas production function as well, with the MLE method which is in a constant *return to scale* condition.

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3.4 Factors affecting the inefficiency of red chili pepper farming

The age of the farmers, their level of education, and their experience of farming Red Chili Peppers have been identified as a potential source of inefficiency in the operation of their farms in the research location. The negative sign on the inefficiency variable reflects that this variable increases the technical efficiency of red chili farming. Analysis of the results indicates that the level of education of the subject farmers shows a significant negative number of 5% (Table 3). This indicates that education and transfer of technical knowledge can significantly increase the efficiency of Red Chili Pepper farming at the study site.

The level of the Farmers education is one metric that can be used to measure the quality of human resources in the area of the study. Farmers who have obtained a higher level of education are in general more likely to adopt innovations presented to them and are interested in being shown any information which can improve their farming operation. Also, in terms of management skills, the better educated farmers will demonstrate better decision-making skills in running their farms.

Table 3. The results of analysis on estimating the technical inefficiency functions of red chili pepper farming in March / April 2016 planting season in Kintamani, Bangli, Bali, Indonesia

Variables	Parameters	Coefficient	*Standard error*	t-rasio
Constant	δ_0	0.285	0.059	4.845**
Farmers' age (year old)	δ_1	0.002	0.004	0.430^{ns}
Farmers' level of education (year)	δ_2	-0.036	0.016	-2.329*
Experience in chili pepper farming	δ_3	0.001	0.005	0.228^{ns}
Sigma squared ($\sigma^2 = \sigma_v^2 + \sigma_u^2$)		0.017	0.002	10.600**
Gamma ($\gamma = \sigma_v^2/\sigma_u^2$)		0.990	0.000	38.261**
Log likelihood function		62.155		
LR test of the one-sided error		17.934		
Mean efficiency		0.862		

Notes: ** = 1% level of significance; * = 5% level of significance; ns = non significant

The value of σ^2 is relatively small (0.017) which reflects its normal distribution. Gamma (γ) parameter is the ratio between technical efficiency (μ_i) variant and total variant (ε_i). The parameter coefficient γ is 0.99 and shows significant effect at 1% level. This figure indicates that 99.00 percent of the variation in the farming of chili pepper (error term) is caused by inefficiency (μi) not from noise (v_i). The gamma value (γ) also indicates that the model is valid because the value is near to 1.

The value of log likelihood function with MLE is 62.155 higher than the value of log likelihood by OLS of 53.188. This higher value indicates that the production function using the MLE method is valid and in accordance with the actual conditions in the field.

3.5 The level of technical efficiency

Generally the average value of technical efficiency is 0.86 which means the average of yield is 86 % from the frontier and it is the maximum value which can be obtained by the optimum farming management. Therefore red chili pepper farming in the location was efficient since the average is > 70%. However, two respondents remain inefficient on their red chili pepper farming since the value is less than 70% [6].

Contrastingly, Sangurjana et al [20] stated that farming operations in Baturiti are inefficient and ineffective in using the production input of Red Pepper farming. The efficiency of farming is dependent on the ability of the farmers to make good decisions based on the information he has available to him and to implement beneficial changes into his farming operations. Extreme climate conditions may also cause inefficient farming since it can force the farmers to use inputs in excess of recommended levels in order to secure crop production.

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4. CONCLUSION

Technically farming operations in Bangli, Bali, Indonesia were done efficiently by the farmers in the study area. Land area, seeds, KCl fertilizer, NPK fertilizer (15:15:15), chicken manure and labor have had a positive effect on increasing the production of large red chili. The excessive use of synthetic insecticides and fungicides can significantly reduce the production if it is applied without considering the recommended control threshold. The level of the farmers'education has been shown to have a positive effect on increasing efficiency or in other words can reduce the inefficiency of Red Chili Pepper farming.

Some areas for improvement identified that could increase Red Chili Pepper production. The land area currently being utilized for production of Red Chili Peppers could be expanded and some of the positive inputs could be better managed particularly increasing the use of fertilizers to recommended levels and using synthetic pesticides and fungicides at the levels recommended by the manufacturers.

The results of studies on the use of natural materials that are technically user friendly as biopesticides are affordable and use locally available materials should be assessed and introduced at the farm level. Simultaneously support from various parties is needed so that these natural biopesticides can be introduced at the farm level and the use of them grown massively.

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