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PRODUCTIVITY AND RESOURCE USE EFFICIENCY IN LENTIL PRODUCTION IN SELECTED AREAS OF BANGLADESH

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Abstract

Optimum use of resources in crop production is crucial for reducing production costs and getting higher profits. Lentil farmers are traditionally using different inputs without considering their efficient use levels. Hence, the present study estimated the productivities of various lentil varieties and measured the resource use efficiency in lentil production. The study analyzed 360 household data collected from 240 improved variety users and 120 local cultivar users spread in the six lentil growing districts namely Faridpur, Magura, Kushtia, Jhenaidah, Manikgonj, and Sirajganj. Along with descriptive statistics, the study used Cobb-Douglas production and resource use efficiency models for analyzing the data. The average productivity of improved variety (1.63 t/ha) was much higher than local cultivars (1.08 t/ha). The highest productivity was found in medium-intensive growing areas due to the use of better variety (BARI lentil 8) and a higher level of inputs. Human labour, seed, TSP, MoP, other fertilizers, pesticides, irrigation, and variety had a positive and significant effect on lentil production. Farmers were not efficient in using inputs, they used excessive amount of labour but less amounts of seed and fertilizers. Lentil farmers faced the lack of suitable land, biotic and abiotic stresses, and lack of improved seeds. Farmers should be supplied with improved variety and production technology to increase farm profits through the efficient use of resources in lentil production.

Keywords: Lentil, productivity, factors of production, resource use efficiency, Bangladesh.

Introduction

Pulses supply nutrition for human diet (Das et al., 2016.), provide feed for the animal (Miah et al., 2009), increase soil nutrient status by adding nitrogen, carbon and organic matter (Senanayake et al., 1987; Zapata et al., 1987; Sarker and Kumar, 2011), and improves farmers' livelihood through additional income. Because of the high protein content and low cost, pulses are called *poor man's meat* (Sumera and Ali, 2020). So, most of the low-income populations can use this nutritious crop as their staple food. However, the per capita consumption of pulse in our country is 15.7 g/day (HIES, 2016) that is much lower than the desirable intake of 50 g/day (DDP, 2013).

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Lentils (*Lens culinaris*) are protein-rich legumes that provide important micronutrients in a rice-based diet (ISPC, 2018). It is the most consumed pulse in the country and ranks first among the pulses in terms of consumers' preferences (Miah and Rahman, 1991; Afzal et al., 1999). Among the pulse crops in Bangladesh (BBS 2021), lentils placed the first position according to area coverage (40% of total pulse area) and production (45% of total pulse production). It is cultivated across the country covering an area of 1.41 lakh hectares with a production of 1.77 lakh metric tonnes with an average yield of 1.26 t/ha. The area and production of lentils were found fluctuating, but the yield registered an increasing trend over the years. However, the annual growth rates of the area decreased by 0.152%, while the growth rates of production (2.62%) and yield (2.77%) significantly increased during 2000/01-2019/20 due to the introduction of improved lentil varieties and management technologies (Miah et al. 2021).

The improved varieties of lentil are suitable for the farmers in terms of productivity and profitability (Miah et al., 2021; Sarker et al., 2020; Matin et al., 2018; Tithi and Barmon, 2018; Hossain et al., 2016). The optimum use of resources in crop production is crucial for reducing the cost of production and getting higher profits. Efficient utilization of inputs has also significant impacts on food security (Chiedozie et al., 2010). But lentil farmers are traditionally using different inputs without considering their efficient use levels. Socio-economists always offer the direction of efficient utilization of inputs to the farmers. Resource use efficiency examines the efficiency of each input and indicates the over-utilization or under-utilization of inputs (Ali et al., 2017). In the past, many authors of home and abroad (Khatun et al. 2019; Ali et al., 2017; Chandra et al., 2017; Dhakal et al., 2015; Umar and Kadir, 2015; Akighir and Shabu, 2011; Chiedozie et al. 2010) estimated resource use efficiency in producing various crops (Rice, mustard, cucumber, tomato, strawberry, etc) except lentils.

Therefore, it is crucial to evaluate the efficiency level of input use to maximize profit by minimizing cost. However, the study on resource use efficiency in lentil production is scarce in Bangladesh. Therefore, the present study was designed with the following objectives: 1) to identify the factors influencing the productivity of lentils at the farm level; 2) to measure the resource use efficiency of farmers in lentil production, and 3) to identify the problems of lentil cultivation in the study areas.

Materials and Methods

Sampling technique and sample size

A multi-stage sampling procedure was followed to select study areas and sample households. Based on the crop concentration index (CCI), the study was conducted in purposively selected six lentil growing districts of Bangladesh, taking Faridpur and Magura districts from highly-intensive (**CCI value = 5.54-11.31*), Kushtia and Jhenaidah districts from medium-intensive (*CCI value = 1.09-4.87*), and Manikgonj and Sirajganj districts from low-intensive growing areas (*CCI value = 0.02-0.83*). Again, in each district two *Upazilas* (administrative unit) and from each *Upazila* one/two Agricultural Blocks (ABs) were purposively selected for collecting data and information from the sample farmers. The *Upazilas* and ABs were chosen in consultation with Agricultural Extension Officer, SAAO, and local BARI scientists. Finally, two lists of lentil growing farmers (adopter and non-adopter) were prepared separately for each AB, and then a total of 30 farmers, taking 20 farmers from adopters and 10 from non-adopters were selected from each *Upazila* for interview. The adopter farmers were those who cultivated improved varieties of lentils and non-adopting farmers cultivated only local cultivars of lentils. Thus, the total numbers of adopting and non-adopting sample farmers were 240 and 120 respectively.

Data collection

Data for the present study were collected by interviewing sample lentil growers with the aid of a pre-designed and pre-tested interview schedule during March to April 2021. Both trained enumerators and researcher collected primary data. Concerning this study, secondary data on lentil area and production were collected and used to supplement the study.

Model specification

The following Cobb-Douglas type production function model was used to estimate the contribution of factors to the productivity of lentils in the study areas. The functional form of the Cobb-Douglas production function model (Gujarati, 2003) is given below (equation 1):

$$Y = \alpha X_1^{b_1} X_2^{b_2} \dots\dots\dots\dots\dots \quad X_n^{b_n} e^{u_i} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (1)$$

The production function was converted to logarithmic form (equation 1) so that it could be solved by the least square method, i.e.

$$\ln Y = \ln\alpha + b_1 \ln X_1 + b_2 \ln X_2 + \dots\dots\dots\dots + b_n \ln X_n + Ui \dots\dots\dots\dots\dots\dots\dots..... (2)$$

The empirical production function model (equation 2) was as follows:

$$\ln Y = \alpha + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \beta_8 \ln X_8 + \beta_9 \ln X_9$$
$$+ \beta_{10} \ln X_{10} + \beta_{11} \ln X_{11} + \beta_{12} X_{12} + U_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

Where,

Y = Yield of lentil (kg/ha)

α = Intercept

β_i = Coefficients of the respective variables to be estimated (i = 1, 2, 3 -----12)

X_1 = Farm size (decimal)

X_2 = Age of the farmer (year)

X_3 = Education (year of schooling)

X_4= Human labour (No./ha)

X_5= Amount of seed (kg/ha)

X_6= Amount of urea (kg/ha)

X_7= Amount of TSP (kg/ha)

X_8= Amount of MoP (kg/ha)

X_9= Amount of other fertilizers (kg/ha)

X_{10}= Cost of pesticides (Tk./ha)

X_{11}= Cost of irrigation (Tk./ha)

X_{12}= Variety dummy (if improved variety=1, Otherwise = 0)

U_i is the error term which is independently distributed with zero mean and constant variance. In addition, one sample t-test was used to find out the significance level of the variation of variables in the regression model.

Resource use efficiency

In order to maximize profit through the efficient allocation of resources, the producer should use more of the variable resource so long as the value of the added production is greater than the cost of the added amount of resource used in the production. The straightforward way of examining such efficiency is to compare the marginal value product (MVP) with marginal factor cost (MFC) of each variable input. The efficiency of inputs used in lentil production was measured by the following equation (4). This approach was used in many past studies (Khatun et al. 2019; Ali et al. 2017; Umar and Kadir, 2015; Dhakal et al. 2015; Abid et al. 2011) for measuring the resource use efficiency.

$$\frac{MVP_x}{MFC_x} = 1 \quad \text{.......} (4)$$

The value of MVP can be estimated using the following equations (5 & 6).

$$MVP_x = MPP_x \times Py \quad \text{.......} (5)$$

$$MPP_x = b_i \times APP_x = b_i \times \frac{Y}{X_i} \quad \text{.......} (6)$$

Where,

MVP_x= Marginal value product of ‘X’ input

MPPx = Marginal physical product of ‘X’ input

APPx = Average physical product of ‘X’ input

MFC_x= PXi = Marginal factor cost of 'X' input (unit price of factor input resource)

Py = Unit price of output

bi = Elasticities or regression coefficients of the various inputs

$\bar{Y}$ = Mean of output

$\bar{X}i$ = Mean of 'X' input factor

The resource is considered to be efficiently used and profit will be maximized when the ratio of MVP to MFC is equal to unity or MVP and MFC for each input are equal. When the ratio is greater than unity, it implies that the resource is underutilized. In that case, there is an ample opportunity to increase total production by increasing the use of specific input in the production process keeping other resources constant. When the ratio is less than unity implying the resource is overused. In that case, it is possible to reduce production cost remains total production unchanged by decreasing the use of specific input.

The relative percentage change in MVP of each resource required to obtain optimal resource allocation, which is MVP = MFC, was estimated using equation 7 below. This formula was also used in different past studies (Khatun et al. 2019; Chandra et al. 2017; Gani and Omonona 2009) in home and abroad.

$$D = [1 - \frac{1}{\frac{MVP}{MFC}}] \times 100 \quad \dots\dots (7)$$

Where, D = Value of percentage change in MVP of each resource. The significance of each explanatory variable was determined using the t-test.

Results and Discussion

Input use pattern

Different types of inputs were used in lentil cultivation. Human labour is one of the crucial inputs that was employed for land preparation, seeding, fertilization, weeding, pesticide spraying, crop harvesting, threshing, drying, and storing. The total number of human labour used for cultivating improved and local lentils was 72 and 63 man-days/ha respectively. The highest number of labour (82 & 74 man-days) was used in the medium-intensive growing areas. They used seeds at the rate of 46 kg and 44 kg per ha for improved and local variety lentils respectively. These rates were a bit higher than the recommended rate (35-40kg/ha). The applications of urea, TSP, and MoP for improved variety lentils in all study areas were a bit higher than the recommended dose. The overall use of inputs was higher for cultivating improved varieties compared to local cultivars and it was true for different growing areas as well (Table 1).

Table 1. Per hectare use of inputs in lentil production in the study areas

Input	High-growing area		Medium-growing area		Low-growing area		All area		Recommen-ded rate
	HYV	Local	HYV	Local	HYV	Local	HYV	Local	
Labour (m-day)	69	61	82	74	66	54	72	63	--
Hired labour	*41*	*38*	*46*	*39*	*42*	*36*	*43*	*38*	--
Family labour	*28*	*23*	*36*	*35*	*24*	*18*	*29*	*25*	--
Seed (kg)	48	47	49	47	42	39	46	44	35-40
Cow dung (kg)	1327	154	4772	4130	718	--	2272	1428	--
Urea (kg)	47	42	48	45	45	41	47	43	40-45
TSP (kg)	92	90	96	91	89	87	92	89	80-90
MoP (kg)	47	40	52	43	46	38	48	40	40-45
Boron (kg)	4.8	2.7	3.9	0.7	1.2	0.2	3.3	1.2	7-10
$ZnSO_4$ (kg)	3.9	2.1	3.8	0.7	0.8	0.6	2.9	1.1	--
DAP (kg)	10.7	8.6	19.0	2.5	7.9	6.8	12.5	6.0	--
Irrigation (Tk.)	2596	2649	1361	681	656	956	1538	1429	*once
Pesticides (Tk.)	1367	1282	1993	1236	770	95	1377	871	--

* Once within 30-40 Days after germination

Productivity of lentils

The average yields of BARI Masur-8, BARI Masur-7, BARI Masur-6, and BARI Masur-4 were 1.86, 1.61, 1.69, and 1.34 tonnes per hectare respectively at the farm level. The average yield gaps of these varieties were found to be 15-31% depending on the variety. However, the average yield of improved varieties (1.625 tonnes/ha) is much higher (33.5%) than that of the local cultivar (Table 2). More-or-less similar yield (1.632 tonnes/ha) was documented in a study conducted in Jashore, Jhenaidah, and Kushtia districts (Hajong et al., 2020). Table 1 further revealed that the yields of both improved and local varieties were higher at the medium-intensive growing areas compared to highly intensive and low-intensive growing areas might be due to the use of higher amounts of inputs and improved varieties.

The productivity of a crop depends on many agro-socio-economic and environmental factors. It varies from variety to variety, location to location, and year to year. Rahman et al. (2012) recorded the average yield of BARI Masur varieties (3, 4, 5, & 6) as 1.733 tonnes/ha in the Jhenaidah and Jashore districts during 2010-11. In the next year (2011-12), Matin et al. (2018) found the average yield of HYV lentils to be 1.479 tonnes/ha in Jashore, Meherpur, and Natore districts. Kazal et al. (2013) recorded lentil yield as 1.160 tonnes/ha in Natore and Bogura districts during 2012.

Table 2. Productivity (kg/ha) of different lentil varieties in the study areas

Lentil variety	High-growing area	Medium-growing area	Low-growing area	All area	**Average potential yield
BARI Masur-8	1832	2017	--	1855 (18)	2250
BARI Masur-7	--	1778	1487	1614 (15)	1900
BARI Masur-6	1676	1793	1445	1692 (21)	2150
BARI Masur-4	--	1456	1326	1339 (31)	1950
All BARI variety	1754	1761	1419	1625 (21)	2063
Local cultivar	1077	1142	1025	1081(33.5*)	--

Note: Figures in the parentheses are percent less yield over potential yield

*Figure in the parenthesis indicate percent lower yield compared to the yield of all improved varieties

** Source: BPH, 2019

Factors influencing the productivity of lentils

The productivity of lentils is likely to be influenced by different factors. The Cobb-Douglas production function model constructed for all areas revealed that the coefficients of human labour, seed, TSP, MoP, other fertilizers, pesticides, and irrigation were positive and significant at 1-10% level, which indicated that 1% increases in those inputs keeping other factors remaining constant would increase the yield of lentil by 0.097%, 0.564%, 0.058%, 0.098%, 0.018%, 0.006%, and 0.005% respectively. It implied that the aforesaid inputs had a positive and significant effect on the yield of lentils. The coefficient of variety dummy was positive and highly significant at the 1% level meaning that 1% increases in the use of improved lentil variety, keeping other factors remaining constant, would increase the yield of lentils by 0.346% (Table 3). The study found some common variables such as seed, TSP, irrigation, and variety dummy in the models constructed for different growing areas which notably influenced the yield of lentils. Only the higher investment in irrigation reduced the yield of lentils in low-intensive growing areas. The results are quite supported by the past studies conducted on lentil production (Rahman et al., 2012; Tithi and Barmon, 2018; Matin et al., 2018). The value of the coefficient of determination (R^2) in model-4 is 0.758 which indicated that around 76% of the variation in output is explained by the independent variables included in the model. The value of F is 90.657 which is significant at 1% level indicates the good fit of the model.

Production function is a functional relationship between outputs and inputs (Jhingan, 2007). There are three stages of production. MPP is negative in stage III and it is not rational to produce with negative MPP (Akighir and Shabu, 2011). However, the returns to scales of lentil production were estimated through the

Table 3. Coefficients of the variables used in the Cobb-Douglas production function

Variables	**Model-1**: High-growing area		**Model-2**: Medium-growing area		**Model-3**:Low-growing area		**Model-4**: All area	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	***4.030	0.455	***2.766	0.575	***4.401	0.474	***3.642	0.276
LnFsize (dec)	-0.028	0.019	***-0.076	0.024	**0.027	0.012	-0.003	0.011
LnAge (year)	-0.017	0.029	0.172	0.136	-0.069	0.092	0.001	0.030
LnEdu (year)	0.002	0.013	0.011	0.018	-0.013	0.012	-0.005	0.008
LnLabour (No.)	0.017	0.070	0.063	0.067	0.077	0.050	***0.097	0.035
LnSeed (kg)	***0.559	0.093	***0.848	0.126	***0.452	0.089	***0.564	0.061
LnUrea (kg)	0.032	0.064	0.074	0.079	0.007	0.064	0.042	0.043
LnTSP (kg)	*0.093	0.051	0.052	0.065	0.006	0.049	*0.058	0.034
LnMoP (kg)	0.083	0.074	0.054	0.076	***0.151	0.054	**0.098	0.042
LnOthfert (kg)	0.010	0.008	0.011	0.010	*0.016	0.009	***0.018	0.005
LnPesticid (Tk)	0.001	0.004	***0.020	0.006	0.005	0.004	**0.006	0.003
LnIrrigati (Tk)	*0.005	0.003	*0.007	0.004	**-0.006	0.003	***0.005	0.002
Variety dummy (BARI=1, local=0)	***0.488	0.028	***0.353	0.037	***0.185	0.026	***0.346	0.018
Returns to scale	1.246		1.589		0.838		1.227	
F-value	50.668***		38.555***		21.266***		90.657***	
R^2	0.851		0.812		0.705		0.758	
N	120		120		120		360	

Note: Dependent variable = Lentil yield (kg/ha)

***, **, * represent significant at 1%, 5% and 10% level respectively summation of all the regression coefficients of inputs in the models for determining the stages of production. It is noted that the returns to scales of lentil production were more than unity for all the models except in model-3 implied that the production function exhibited increasing return to scale and lied on the first stage of production. This also implied that when all other variables are held constant, a unit increase in one of them results in higher than proportionate increase in output. However, only the production function of low-growing areas (model-3) showed decreasing returns to scale and reclined in the second stage of production. It indicates that if all the inputs specified in the production function were increased simultaneously by 100%, the yield would increase by 84% (Table 3).

Resource use efficiency

The ratios of MVP and MFC are greater than unity for seed, urea, TSP, MoP, and other fertilizers (Boron, ZnSo4 & DAP) indicating that these inputs were underutilized. The lentil farmers in the study areas used small amounts of these inputs to cultivate lentil meaning that the cost of using these inputs is less than the value of marginal product. The findings suggest that farmers can invest more on these inputs to ensure the use of these inputs efficient. The ratio of MVP and MFC for labour is less than unity implying that such key input was over utilized. This suggests that farmers can reduce the number of labour to make its use efficient. Overall, the study revealed that all the inputs used in lentil production were not optimally utilized (Table 4).

Table 4 further reveals that the adjustment in the MVPs indicated that the level of input use should be increased or decreased for optimal allocation of resources. The level of use of seeds, urea, TSP, MoP and other fertilizers should be increased by 91%, 81%, 57%, 92% and 46% respectively to obtain the optimum profit. On the other hand, human labour was needed to decrease by 160% for getting the highest profit.

Table 4. Estimated resource use efficiency indicators in lentil production

Variable	Coefficient	MPP	Py	MVP	MFC	MVP/ MFC	Adjustment required (%)
Labour (man-day)	0.097	1.944	68.5	133.16	345.60	0.385	-160
Seed (kg)	0.564	16.958	68.5	1161.62	102.50	11.333	91
Urea (kg)	0.042	1.288	68.5	88.23	16.66	5.296	81
TSP (kg)	0.058	0.867	68.5	59.39	25.65	2.315	57
MoP (kg)	0.098	3.014	68.5	206.46	16.11	12.816	92
Other fertilizers (kg)	0.018	1.804	68.5	123.57	67.37	1.834	46

Problems of lentil cultivation

The adopter and non-adopter farmers in the study areas mentioned numerous common issues regarding the problems of lentil production, but the magnitudes of their statements were not the same at all. The majority of the farmers (40-53.3%) opined about the attack of foot rot and stemphylium blight diseases. The leaves of the infected plants become yellow or reddish after 20-25 days of sowing, and the tip of the plant dries slowly due to attack of foot rot disease. This problem was more vital for local cultivars compared to improved varieties. Adverse weather (dense fog, excessive rain, heat, etc.) was another severe problem faced by 15.4-19.2% of respondent farmers. The infestation of lentils by insects (Aphids & cutworm) was reported by 8.3-9.2% of the farmers to be harmful for lentil cultivation. Some respondent farmers were facing the unavailability problem of quality lentil seed in the study areas. The lower yield of local lentils was mentioned as a crucial problem by 15% of non-adopter farmers. The other problems of adopters and non-adopters were lack of cash, the higher price of labour, and the low market price of lentils (Table 5).

Table 5. Problems of lentil cultivation in the study areas

Type of problems	Improved variety user (n=240)		Local cultivar user (n=120)	
	N	%	N	%
1. Infection of foot rot & stemphylium diseases	96	40.0	64	53.3
2. Adverse weather (fog, excessive rain, heat)	37	15.4	23	19.2
3. Lack of irrigation facility	28	11.7	12	10.0
4. Infestation of insects (Aphids, *Katui*)	22	9.2	10	8.3
5. Lack of quality seed	10	4.2	8	6.7
6. Lack of cash	15	6.3	7	5.8
7. Scarcity and higher cost of labour	12	5.0	8	6.7
8. Low yield	7	2.9	18	15.0
9. Low market price	5	2.1	3	2.5
10. Others*	8	3.3	6	5.0

Note: *Higher cost of inputs, low germination of seed, crop dies due to excessive salt, lack of tillage machinery, bad soil quality, etc.

Conclusions

Three variables namely seed, irrigation and variety had a positive and significant effect on lentil production. Farmers used excessive amount of labour but less amounts of seed and fertilizers to produce lentils. However, the level of adjustments for using various resources to earn optimum returns will serve as a bench-mark guideline for the lentil growers, government agencies, and agro-based companies. However, some lentil farmers in all the study areas were to some extent constrained by suitable land, biotic and abiotic stresses, and quality seeds for the desired level of lentil production.

The study suggests concerned agencies to supply improved and disease registrant lentil varieties and provides sufficient irrigation facilities to increase productivity and farm profits of the farmers. Farmers should be encouraged to use farm machineries for escaping from human labour crisis. Lentil farmers should be given hands-on training for ensuring the efficient use of resources. Thus if proper uses of resources could be ensured, lentil production could be a more viable and attractive commercial enterprise to the farmers.

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