Title: Economic Impact of Lentil Cultivation on Marginal and Small Farm Households in Eastern India

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Abstract: An unsatisfactory gain in pulse productivity since last six decades in India emerges severe threat to the overall food and nutritional security and also resilient livelihood of the nation. Due to failure of National Food Security Mission, International Centre for Agriculture Research in the Dry Areas (ICARDA) has started a multi-disciplinary project to enhance lentil productivity under rice-based cropping systems in West Bengal India. The present study attempts to evaluate the economic impact of ICARDA with regards to change in lentil productivity, level of input use and key factor contributor with respect to traditional lentil growers. Overall 507 sample farm households under ICARDA and non-ICARDA were taken into consideration. There was a 33.36% estimated change in lentil productivity under ICARDA over traditional growers where the technological change has contributed 24.93% and gap due to technical substitution of input covered 8.42% change. Proper land preparation, quality seed use and better disease pest management became the prime factor behind the enhancement of lentil productivity. Overall cost benet ratio for lentil has registered 1.24 for the state. Year of farming experience became the prime contributor regarding technology adoption of farm households where 90% farm households belong to low and poor economic status.

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Economic impact of lentil cultivation on marginal and small farm households in Eastern India

Introduction

Lentil is one of the most nutritious cool season food legume crops grown around the world.It has been a part of the human diet since the aceramic (before pottery) Neolithic times, being one of the first crops domesticated in the Near East. Archeological evidence shows that the crop was eaten 9,500 to 13,000 years ago. Lentil colours range from yellow to red-orange to green, brown and even black. Lentils also vary in size, and are sold in many forms, with or without the skins, whole or split (Erskine *et. al.* 2011). Today, approximately half of the world's area (48.2%) under lentil cultivation is in southern Asia, where indigenous lentils are of a specific ecotype with a marked lack of variability.

Lentil in World Perspective: An Overview

Lentil production for the major lentil producing nations has been trending upwards during the past 7 years, ranging from 2.1 million tonnes (Mt) in 2002-2003 to 2.9 Mt in 2009-2010 and 5.9 Mt in 2018. Among the main producers, all the leading countries are showing fluctuating and varying level of production over the years. However production increases after 2014 in all the leading countries. Lentils are relatively tolerant to drought, and are grown throughout the world. The FAO reported that the world production of lentils for calendar year 2009 was 3.917 million metric tons which is gone upward to 6.3 Mt in 2018, primarily coming from Canada, India, Turkey and Australia (UN Food & Agriculture Organization Report 2019). About a quarter of the worldwide production of lentils is from India, most of which is consumed in the domestic market. Canada is the largest export producer of lentils in the world and Saskatchewan is the most important producing region in Canada. Statistics Canada estimates that Canadian lentil production for the year 2018 is a record 3.2 million metric tons with highest per capita production of 87.0 kg.

Leading Exporters Country of Lentil in World

Canada being the leading exporters of Lentil in the world comprising bulk of the share (48.2 per cent to total) followed by Turkey (11.8 per cent), Australia (10.7 per cent), United Arab Emirates (6.5 per cent) and United States of America (5.2 per cent). India rank 11th after Egypt with only 0.7 per cent export share in world(source: http://www.worldstopexports.com/top-lentils-exporters-by-country/).

Lentil in India: An Overview

Lentils are grown throughout northern and central India mainly for their grains, which are used for traditional *Dal* (whole dehulled) as well as other culinary preparations. Pulses are considered to be the cheapest sources of proteins among all foods and, therefore, have a significant place in improving nutrition at the individual as well as the country level. It is the development of short-duration and heat-tolerant varieties and better management that have helped in improving yields (Suresh and Reddy, 2013). Lentil is one of the most nutritious cool season food legume crops in India occupying a 1.42 million ha area with a production of 1.17 million tonnes and a productivity of 828.00 kg/ha (5-year average between 2013-14 to 2017-18) (Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India eands.dacnet.nic.in). Traditionally pulses have been considered important elements of cropping systems in the Indo-Gangetic Plains. They were popular because of their importance as a source of protein and ability to fix atmospheric nitrogen (N) and thus improve soil fertility (Joshi 1998). With the introduction of irrigation and due to high profitability of alternative sources of soil nutrients in the form of inorganic fertilizers in the mid 1960s, pulses were replaced or relegated to marginal lands. During the late 1960s and early 1970s, a large area under pulses in the Indo-

Gangetic Plain (IGP) was substituted by high-yielding varieties of rice (*Oryza sativa*) and wheat (*Tritium aestivum*). The new technology of rice and wheat substantially changed the agricultural scenario and largely contributed to increase in agricultural production in the IGP. With the passage of time, excessive use of chemical fertilizers and irrigation in rice and wheat to maintain their productivity has created an imbalance in soil fertility and threatened the sustainability of the most productive food grain belt in South Asia (Hobbs and Morris 1996). Thus, pulses are an effective source of reversing the process and can contribute significantly to achieving the twin objectives of increasing productivity and improving the sustainability of the rice and wheat-based cropping system in the IGP (Ahlawat *et al.* 1998; Lauren *et al.* 1998; Yadav *et al.* 1998). It has been reported at various level of research that there is an ample scope of increasing area under lentil during the *rabi* season, as its cost per hectare is less with higher net returns than the competing crops like wheat, gram and mustard in water-deficit and resource-poor conditions. There are large returns for adoption of disease management (80 per cent increase in net return), and improved small-seeded varieties (about 40 per cent increase in net return) in lentil. Thus lentil-based cropping systems would be more profitable with higher level of water productivity that is suitable for mostly un-exploited rice-fallows under water-deficit conditions in India (Reddy and Reddy 2010). With the advent of 11th Five Year Plan, National Food Security Mission (NFSM)was launched allover India for 17 states and 312 districts in order to increase the cereal and pulse production by at least 20 million tonnes by 2012 apart from the usual year to year production. But unfortunately, the effort is in vain as none of the NFSM-pulses districts in India could achieve the targeted production level due to lack of adequate financial flow and thereby inadequate delivery of physical components of production (Chatterjee and Giri 2010).

Lentil is most important pulse in *rabi* season grown mainly in Uttar Pradesh, Madhya Pradesh, Chattishgarh, Bihar and West Bengal. These states all together account for 80-90% of the total area under lentil. In Bihar, lentil production mainly comes from the districts of Patna (27722 ha), Aurangabad (13612 ha), Nalanda (12013ha) and West Champaran (10238 ha). The productivity of lentil is highest in Patna district (1489 kg/ ha). Major varieties which are under cultivation in Bihar are PM-5, Pant L-406, DPL-62, Arun, HUL 57 etc. Among the major pulse crops in West Bengal, lentil has prime importance. Lentil was grown mainly in Nadia (24135 ha), Murshidabad (16922 ha), North 24-Parganas (7844 ha) and Birbhum (5864 ha) districts of West Bengal. The maximum productivity of 1145 kg/ha comes from Murshidabad district. Major varieties under cultivation are WBL-58, B-77 etc. It is the development of short-duration and heat-tolerant varieties and better management that have helped improve yields (Suresh and Reddy, 2013). The crop is generally grown as a rainfed one in West Bengal and the seeds are generally broadcast instead of being sown in line. It is grown as a *paira* crop in a standing crop of rice 7 to 10 days before the rice is harvested (relay cropping). This technique capitalizes on the residual moisture of the first crop, ensures timely sowing, virtually guarantees germination and avoids tillage operations. There is tremendous potential for growing lentil as a *paira* crop in the lower Gangetic belt of West Bengal, particularly in Nadia and Murshidabad districts.

During independence, the total productivity of pulses grown in India was 567 kg/ha (1947-48). This was raised to just 699 kg/ha in 2011-12 because suitable seed varieties were not available. Considering the importance of the crop in terms of its nutritive values, productivity must be raised to a certain extent using improved technology and an improved package of practices. The International Centre for Agriculture Research in the Dry Areas (ICARDA), in a joint collaboration with the India-Morocco Grain Legume Initiatives, has started a multi-disciplinary project to enhance lentil productivity under rice-based cropping systems in the Gangetic alluvial plains of West Bengal India since 2011-12. ICARDA has provided improved technology and an improved package of practices to farmers during the last eight years in order to enhance lentil productivity and to meet livelihood requirement in this region. So, there is a very basic need to assess the socio-economic impact of lentil cultivation on farm households with improved package of practices and technology provided by ICARDA over the years in the lower gangetic alluvial plains of West Bengal, India.

Thus, the present study has undergone some specific objectives as:

- To evaluate the technological change in lentil cultivation prior to the initiation of ICARDA in West Bengal India (2008-09 to 2013-14)
- To assess the economic impact of lentil production with improved package of practices provided by ICARDA in this region
- To compare the differences in socio-economic livelihood status of the lentil growers under ICARDA and traditional cultivators in the region

Materials and Methods

Research Methodology

Data Envelopment Analysis (DEA-Malmquist Indices)

To evaluate the level of total factor productivity (TFP) change in lentil cultivation in West Bengal over the period 2008-09 to 2013-14 prior to the initiation of ICARDA and to disaggregate the TFP change into technical change and efficiency change DEA-Malmquist productivity indices have been performed using DEAP 2.1 software version. Data on area, production, and productivity of lentil production in the state of West Bengal for the growing seasons 2008-09 to 2013-14 have been collected from the websites of the Directorate of Economics and Statistics (DES), Ministry of Agriculture, Government of India (http://aps.dac.gov.in/APY/Public_Report1.aspx and http://eands.dacnet.nic.in/Cost_of_Cultivation.htm). Data on five input factors – seed (kg), nitrogen, phosphorus and potassium (NPK) fertilizer (kg), plant protection chemicals (gm ha^{-1}), bullock labor (pair hours), and human labour (hours) – were also collected

DEA is a linear programming methodology that uses data on the input and output quantities of a group of states to construct a piece-wise linear surface over the data points. This frontier surface is constructed by the solution of a sequence of linear programming problems – one for each state in the sample. The degree of technical inefficiency of each state (the distance between the observed data point and the frontier) is produced as a byproduct of the frontier construction method.

The Malmquist total factor productivity (TFP) index

The Malmquist productivity index makes use of the distance functions to measure productivity change.It can be defined using input or output-oriented distance functions.This approach was first proposed by Caves et al. (1982) and later by Coelliet al. (2003a). We look only at the output-oriented Malmquist productivity index (MPI).

Using period s technology:

$$m_o^s(q_s, q_t, x_s, x_t) = \frac{d_o^s(q_t, x_t)}{d_o^s(q_s, x_s)}$$

Using period t technology:

$$m_o^t(q_s, q_t, x_s, x_t) = \frac{d_o^t(q_t, x_t)}{d_o^t(q_s, x_s)}$$

Since there are two possible multifactor productivity (MFP) measures, based on period s and period t technologies, the MFP is defined as the geometric average of the two:

$$m_o(q_s, q_t, x_s, x_t) = [m_o^s(q_s, q_t, x_s, x_t) \times m_o^t(q_s, q_t, x_s, x_t)]^{0.5} = [\frac{d_o^s(q_t, x_t)}{d_o^s(q_s, x_s)} \times \frac{d_o^t(q_t, x_t)}{d_o^t(q_s, x_s)}]^{0.5}$$

It can be decomposed into an efficiency change and a technical change and the product is termed as the MPI.

$$m_o(q_s, q_t, x_s, x_t) = \frac{d_o^s(x_t, q_t)}{d_o^s(x_s, q_s)}[\frac{d_o^s(x_t, q_t)}{d_o^t(x_t, q_t)} \times \frac{d_o^s(x_s, q_s)}{d_o^t(x_s, q_s)}]^{0.5}$$

The first part of the product $\frac{d_o^s(x_t, q_t)}{d_o^s(x_s, q_s)}$ is due to the efficiency change of the farmer and the second part $[\frac{d_o^s(x_t, q_t)}{d_o^t(x_t, q_t)} \times \frac{d_o^s(x_s, q_s)}{d_o^t(x_s, q_s)}]^{0.5}$ is due to the technical change of the inputs.

A correlation and multiple stepwise regression between lentil productivity ($kgha^{-1}$) in West Bengal and its input use were performed in order to identify the factor most contributing towards the change in yield over the period under study (2008-09 to 2013-14).

To confer the second objective, Bisaliah (1976) method of decomposition technique has been used to compare the regression coefficient of various input use and output produced between ICARDA and traditional lentil cultivators. Allover a sum total of 507 farm households (249 number of ICARDA farmers and 258 traditional lentil growers)) were surveyed and taken into regression model fitting, covering six major lentil producing districts in the lower gangetic belt of West Bengal, India.

Hypothesis behind the study

H_0: There is no significant change in production technology with improved package of practices under ICARDA over traditional lentil growers in West Bengal

The corresponding alternative hypotheses would be H_1

H_1: There is significant change in production technology with improved package of practices under ICARDA over traditional lentil growers in West Bengal

To sort out the contribution of technology and resource use differences from the total productivity difference between using the improved package of practices and traditional lentil cultivation methods the log linear production function (Cobb-Douglas production function) was specified for both technologies. Specifically:

$$Y = aX_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}X_5^{b5}X_6^{b6}X_7^{b7}u_i \qquad (1)$$

The production function was specified on a per hectare basis since the purpose is to compare productivity differences per hectare. Where

Y is the lentil yield (kg ha^{-1})

X_1 is the quantity of seed used (kg ha^{-1})

X_2 is the quantity of NPK used (kg ha^{-1})

X_3 is the quantity of Organic Manure used (kg ha^{-1})

X_4 is the quantity of plant protection chemicals used (gm/ml ha^{-1})

X_5 is the amount of machine labour used (hour ha^{-1})

X_6 is the amount of bullock labour used (pair hour ha^{-1})

X_7 is the amount of human labour used (man-days ha^{-1})

u_i is a random disturbance term in conformity with the ordinary least squares assumptions

b_i is a regression coefficient of respective parameters

a is a scale parameter or intercept.

Before proceeding with the decomposition analysis of the productivity difference between the improved packages of practice and traditional ones, it is necessary to determine whether there is a structural break or not in the production relations between improved and traditional cultivation packages. To identify this, output elasticities were estimated by ordinary least squares method by fitting the log linear regression separately for improved and traditional farmers. The pooled regression analysis was run in combination with those for the improved and traditional packages, including a dummy variable for improved technology. The dummy variable was set at 1 for improved technology and 0 for the traditional lentil cultivators.

The following equations derived from the equations were estimated by identifying the structural break:

$$\ln Y_{imp} = \ln\beta_0 + \beta_1\ln X_1 + \beta_2\ln X_2 + \beta_3\ln X_3 + \beta_4\ln X_4 + \beta_5\ln X_5 + \beta_6\ln X_6 + u_{imp} \ldots\ldots\ldots \quad (2)$$

$$\ln Y_{trad} = \ln\alpha_0 + \alpha_1\ln X_1 + \alpha_2\ln X_2 + \alpha_3\ln X_3 + \alpha_4\ln X_4 + \alpha_5\ln X_5 + \alpha_6\ln X_6 + u_{trad} \ldots\ldots\ldots \quad (3)$$

$$\ln Y_{pooled} = \ln \gamma_0 + \gamma_1\ln X_1 + \gamma_2\ln X_2 + \gamma_3\ln X_3 + \gamma_4\ln X_4 + \gamma_5\ln X_5 + \gamma_6\ln X_6 + \gamma_7\ln X_7 + u_{pooled} \ldots\ldots\ldots \quad (4)$$

Equation (2) and equation (3) represent the multiple regression equations for lentil cultivators using the improved technology and traditional cultivators. Equation (4) represents the pooled regression model, including traditional and improved cultivators and including a dummy variable (X_7).

Decomposition and analytical model

Equations (2) and (3) were estimated using the OLS technique. Since the production function is per unit area (hectare), multi-collinearity was not a problem as indicated by the zero-order correlation matrix. Taking the difference between equations (2) and (3), performing slight algebraic manipulations, and rearranging some terms, the following decomposition model was arrived at:

$$[\ln Y_{imp} - \ln Y_{trad}] = [\ln\beta_0 - \ln\alpha_0] + [\ln X_{1trad}(\beta_1-\alpha_1) + \ln X_{2trad}(\beta_2-\alpha_2) + \ln X_{3trad}(\beta_3-\alpha_3) + \ln X_{4trad}(\beta_4-\alpha_4) + \ln X_{5trad}(\beta_5-\alpha_5) + \ln X_{6trad}(\beta_6-\alpha_6)] + [\beta_1\ln(X_{1imp}/X_{1trad}) + \beta_2\ln(X_{2imp}/X_{2trad}) + \beta_3\ln(X_{3imp}/X_{3trad}) + \beta_4\ln(X_{4imp}/X_{4trad}) + \beta_5\ln(X_{5imp}/X_{5trad}) + \beta_6\ln(X_{6imp}/X_{6trad})] + [u_{imp} - u_{trad}] \ldots (5)$$

The left-hand side of the equation gives the total difference in productivity (expressed as a percentage) over traditional practices. The natural logarithm of the ratio of per hectare output of the improved practices to that of traditional practices is approximately a measure of the percentage difference in output of the two different practices. The first bracketed term on the right-hand side, the difference between the natural logarithms of the constant terms, is the gap attributable to the neutral component of the technology. It is a measure of the neutral technology gap between lentil cultivators using an improved package of practices and those following traditional practices. The second bracketed term is the gap attributable to the non-neutral component of the technology by input use for traditional practices. That is a measure of the non-neutral technology gap, after adjustment for the level of input use between two practice situations. The third bracketed term refers to the gap attributable to the difference in input use by the slope coefficient of the productivity function fitted for the improved package of practices recommended by ICARDA. Hence, it is the gap due to difference in the level of input use between the improved and traditional practices in lentil cultivation, after making adjustments for the production elasticities of different input. The last component is the random error term, which the model could not consider (Feder and O'Mara, 1981).

F test:

To measure the changes between traditional and improved Lentil growers, overall regression analysis with F test has been performed. If there are *n* data points to estimate parameters of both models from, then one can calculate the *F* statistic, given by:

$$F = \frac{(RSS1 - RSS2)/(p2 - p1)}{(RSS2/n - p2)}$$

where RSS_i is the residual sum of squares of model *i*. If the regression model has been calculated with weights, then replace RSS_i with χ^2, the weighted sum of squared residuals. Under the null hypothesis that model 2 does not provide a significantly better fit than model 1, *F* will have an *F* distribution, with $(p_2 - p_1, n - p_2)$ degrees of freedom. The null hypothesis is rejected if the *F* calculated from the data is greater than the critical value of the *F*-distribution for some desired false-rejection probability (e.g. 0.05). The *F*-test is a Wald test.

To confer the third objective, socio-economic livelihood status of the sample farm families have been worked out based on the following parameters:

a. Age

b. Sex

c. Educational level

d. Caste

e. Operational Holding size (ha)

f. Non-farm income per annum

g. Total valuation of assets

h. Gross return from crop + animal husbandry

i. Total consumption expenditure

On the basis of following parameters, principal component analysis (PCA) is performed to identify the various factor contribution and variability of each component so that the sample farm households can be categorized into four distinct clusters with specific characteristic features with regards to high medium low and poor socio-economic status.

Site description

The study mainly focuses on six major lentil producing districts comprising of fifteen blocks and twenty-one villages of West Bengal covering 507 farm households under lentil cultivation in the lower gangetic plains of India.However, there are varied cropping systems adopted by the lentil cultivators across districts andregions of West Bengal. Farmers usually follow Jute-Lentil-Moong or any other vegetables in their cropping sequences in Karimpur blocks of Nadia district where Lentil is cultivated after harvest of Jute (in October) with proper land preparation techniques with 2-3 ploughings by tractor followed by one laddering by bullock labour. Seeds are generally broadcastedhere to grab the residual moisture of the land. In Chakdah and Haringhata regions, farmers usually follow Paddy-Lentil-Vegetables/Sesame/Mustard cropping systems where lentil is usually cultivated as *paira* cropping (relay cropping) and seeds are broadcasted 7-10 days before harvest of late *kharif* rice to grab the residual moisture of the soil without proper land preparation. In Krishnanagar block, farmers are usually cultivated lentil in growing mustard field or even in between the spaces of banana orchard following simple broadcasting method without maintaining any proper land preparation methods or techniques. This picture was a common one across all the regions and districts where hardly few regions have followed proper land preparation techniques for lentil. There was a seed production programme going on in Goghat block of Hooghly district West Bengal where about 100 acres of land was under Lentil seed production programme. WBL-77 (Moitrayee) and L-4717, an early maturing variety of 100-105 days recommended by the State Seed Corporation, Govt. Bengal was cultivated for seed production. Farmers usually followed proper land preparation methods here with 2-3 ploughing followed by one laddering with line sowing (60 to 75 cm between rows and 15 to 20 cm between plants with a seed rate of 12-15 kg per hectare).The summary statistics of socio-economic livelihood status of the surveyed farm households (ICARDA and non-ICARDA) is cited in Table 1.

Table 1. Summary statistics of socio-economic status for the surveyed lentil cultivators (ICARDA and non-ICARDA) in West Bengal India

Parameters	Units	Districts						
		Nadia	24-Parganas (N)	Bankura	Purulia	Murshidabad	Hooghly	Overall
		Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Farmer's age	Years	52±10.92	48±7.31	44±4.91	40±4.23	44±9.40	48±12.47	48±10.44
Sex/Gender	Code	1±0.00	1±0.00	1±0.28	1±0.51	1±0.44	1±0.14	1±0.27
Education	Code	3±0.93	3±0.72	3±0.54	2±0.62	3±0.72	2±0.66	2±0.85
Religion	Code	1±0.46	1±0.20	1±0.00	1±0.00	1±0.00	1±0.14	1±0.32
Caste	Code	3±0.90	3±1.17	3±1.14	3±0.56	3±1.48	2±0.93	3±1.07
Cultivated own land	Hectare	0.76±0.56	0.73±0.53	1.05±0.80	0.69±0.19	0.75±0.64	0.81±0.74	0.80±0.63
Non-cultivated land	Hectare	0.00±0.00	0.12±0.24	0.00±0.00	0.00±0.00	0.00±0.00	0.50±0.61	0.11±0.34
Leased in land	Hectare	0.13±0.28	0.05±0.12	0.06±0.20	0.00±0.00	0.00±0.00	0.23±0.33	0.11±0.25
Leased out land	Hectare	0.05±0.24	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.09	0.02±0.15
Total operational holding	Hectare	0.83±0.51	0.90±0.49	1.11±0.77	0.69±0.19	0.75±0.64	1.12±0.81	0.88±0.61
Non-farm income	₹annum^{-1}	84223±66144	31313±29696	36692±23615	10822±2975	6938±5163	67859±120264	54670±74312
Total valuation of current assets (including land, pond, dwelling house and farm machineries)	₹annum^{-1}	2735966±2529459	825985±711276	763628±543540	347043±86853	1444502±1213960	1138739±1203098	1594429±1914255
Gross return from farm enterprises	₹annum^{-1}	167947±87857	93482±43503	91076±60718	66366±18614	73280±20002	143074±143204	126054±96349
Total consumption expenditure	₹annum^{-1}	103977±29653	100738±27147	66514±30080	55783±6313	97901±12750	131633±72590	98876±46378

SD, Standard deviation

Note: Code for Sex/Gender: Male-1 Female-2 Education: Illeterate-1 Upto primary-2 High school-3 Graduate and above-4 Religion: Hindu-1 Muslim-2 Caste: Scheduled Caste-1 Scheduled Tribe-2 Other backward class-3 General-4 Others-5

Results

Measurement of technological change in lentil cultivation for West Bengal India during 2008-09 to 2013-14

To evaluate the technological change in lentil cultivation prior to the impact of ICARDA in the state of West Bengal India, DEA-Malmquist TFP indices has been worked out for the state where the mean effect of technology has been recorded 1.376 for the state.However, the entire TFP change has been segregated into technical and efficiency change (Table 2) and it has been guided by the technical substitution of input, not by the farmers' efficiency or knowledge gaining. Whilecorrelation and step-wise regression analysis between lentil productivity and various input used during these years have shown unavailability of suitable HYV seeds (Table 3 and 4). Farmer's negligence in adopting proper land preparation and seed sowing techniques was also a big issue in this region as most of the farmers have grown lentil as relay crop just after winter rice. Seeds are usually broadcasted here without proper tilling before sowing just to capture the residual moisture of the soil. However, ICARDA has entered in the state with improved level of technology and improved package of practices to enhance the productivity of lentil in West Bengal.

Table 2. Malmquist index summary for lentil in West Bengal (2008-09 to 2013-14)

Year	EFFCH	TECHCH	TFPCH
2009-10	1.000	1.326	1.326
2010-11	1.000	1.333	1.333
2011-12	1.000	2.066	2.066
2012-13	1.000	0.906	0.906
2013-14	1.000	1.493	1.493
Geometric mean	**1.000**	**1.376**	**1.376**

Note: EFFCH – efficiency change; TECHCH – technical change; TFPCH: – total factor productivity change

Table 3. Pearson correlation matrix between lentil productivity with various inputs used in West Bengal during 2008-09 to 2013-14

	Y	X_1	X_2	X_3	X_4	X_5
Y	1.000	0.831* (0.040)	0.751 (0.085)	-0.175 (0.741)	0.059 (0.911)	0.289 (0.579)
X_1		1.000	0.674 (0.142)	-0.211 (0.689)	-0.088 (0.867)	0.342 (0.507)
X_2			1.000	-0.359 (0.485)	-0.303 (0.559)	-0.352 (0.493)
X_3				1.000	0.773 (0.071)	0.485 (0.329)
X_4					1.000	0.584 (0.224)
X_5						1.000

Note: Y is lentil productivity (kg/ha); X_1 is seed use (kg.); X_2 is NPK use (kg); X_3 is organic manure (Qtl.); X_4 is bullock labor (pair hour) and X_5 is human labor (hour)
Figures in the parentheses indicate the respective probability value of the correlation coefficient
* means significant at the $P_{0.05}$ level

Table 4. Stepwise regression output between lentil productivity with various inputs used in West Bengal during 2008-09 to 2013-14

Regression equation	Contributing factor	Remarks
$Y = -0.235 + 0.196 X_1$*	X_1: seed	Lack of quality seed is the sole contributing factor beyond the overall productivity change of lentil

Note: * means significant at $P_{0.05}$ level

Comparative study on economics of lentil cultivation among ICARDA and non-ICARDA farm households in West Bengal India

Regarding comparative economics of lentil cultivation among ICARDA and non-ICARDA farm households across districts and regions of West Bengal, the traditional lentil cultivators are lacking far behind of the ICARDA farmers in terms of Lentil productivity, Gross return received per hectare and Economic return as well. However there is a massive loss of (30 paise) per rupee of investment in Lentil cultivation for the traditional farmers in West Bengal. This is because of the lack of improved seeds, good seed treatment chemicals, cultivation technology and efficient labour use. Productivity of lentil has gone up to a mammoth 39.72% over the traditional cultivators. Organic manure, plant protection chemicals and bullock labour use is much more for the traditional cultivators. Traditional cultivators are using more and more plant protection chemicals as cost per hectare is more than double than that of ICARDA farmers. This is because of the severe disease pest infestation without using proper seed treatment chemicals at the time of sowing and also they are following broadcasting method called utera cultivation (*paira* cropping) i.e. sowing seed prior to harvest of *kharif* paddy in the field to utilize the residual soil moisture for the germination of Lentil seeds. But this causes severe soil borne pathogen to attack the baby plant. That's why PPC is utilized much more for the traditional farmers but unscientifically as yield is reduced to 740 kg/ha for them. Also proper remunerative price was not receivedby the traditional farmers for their produce. The wholesale market price is shown much lower (Rs. 36 per kg.) than that of average price of West Bengal (Rs. 44/-) (Table 5).

Table 5. Comparative Economics of lentil cultivation among ICARDA and non-ICARDA farm households in West Bengal India

Item	ICARDA	non-ICARDA	Overall
Operational Holding (Hectare)	0.91	0.68	0.88
Area under Lentil (Hectare)	0.24	0.12	0.22
Quantity seed use (kgha^{-1})	37.45±15.28	32.62±4.83	34.99±11.49
Seed cost (₹ha^{-1})	2,495/-	1,742/-	2,384/-
Quantity NPK use (kgha^{-1})	94.76±73.40	80.67±46.24	87.59±61.45
NPK cost (₹ha^{-1})	9,464/-	3,374/-	8,567/-
Quantity manure use (qha^{-1})	11.43±13.12	9.64±1.03	10.52±9.26
Manure cost (₹ha^{-1})	873/-	162/-	768/-
PPC use (g or mllit^{-1}ha^{-1})	133.00±178.22	186.05±197.70	160.00±190.06
PPC cost (₹ha^{-1})	3,998/-	8,758/-	4,699/-
Irrigation cost (₹ha^{-1})	NIL	NIL	NIL
Machine labour use (hours ha^{-1})	15.47±9.23	12.50±8.47	13.96±8.97
Machine labour cost (₹ha^{-1})	6,963/-	4,988/-	6,672/-
Bullock labour use (pair hours ha^{-1})	7.91±6.29	9.36±7.58	8.65±7.01
Bullock labour cost (₹ha^{-1})	779/-	1,343/-	862/-
Human labour use (man daysha^{-1})	90.37±43.30	97.62±56.73	94.06±50.66
Human labour cost (₹ha^{-1})	18,278/-	16,840/-	18,066/-
Total operational cost (₹ha^{-1})	42,851/-	37,208/-	42,020/-
Productivity (q ha^{-1})	10.60±6.22	7.59±2.62	9.91±5.29
Price (₹kg^{-1})	45/-	36/-	44/-
Gross return (₹ha^{-1})	56,621/-	26,735/-	52,220/-
Net return (₹ha^{-1})	13,771/-	(-)10,473/-	10,201/-

B:C ratio	1.32	0.71	1.24

Note: Mean±SD

Regression function estimates of lentil cultivation under improved technology compared with traditional lentil cultivators

The table (Table 6) identifies the regression function estimates for lentil cultivation under improved technology and compares these with those of traditional lentil growers. It shows that there is a highly significant change between the lentil growers with improved technology for the traditional cultivators as F statistics appeared to be very high (51.09) as compared to critical value (1.96). So it would be highly permissible to go for the individual regression analysis of traditional and improved lentil cultivators separately to examine the changes in input use and productivity. But individual regression model also shown F calculated value appeared to be larger than tabular value indicating there is still some significant difference among traditional and improved lentil growers regarding input use and output gained and they are not statistically at par. Inspite of applying same level of input and adviced technology, still some significant differences have been observed among the lentil growers under ICARDA. It may be knowledge gaining by individual cultivators that may make significant differences amongst them. R^2 value appeared to be not high (0.38), still showing significance because of large number of samples. An efficient use of machine labour and human labour have shown significant contribution and important factor for improved cultivators as compared to traditional one and has shown subsequent impact to the regression model as a whole. So land preparation is showing some significant positive contribution on overall productivity gaining of Lentil under ICARDA, although contribution of other factors like seeds, fertilizer, manure have shown no real significant effect on the productivity of Lentil in West Bengal as a whole. PPC have a significant impact on lentil cultivation under ICARDA in the state.

Table 6. Regression estimates in lentil cultivation under improved technology adoption and traditional lentil cultivation (per ha) in West Bengal INDIA

Serial number	Particulars	Parameters	Lentil growers using improved ICARDA technology	Traditional lentil growers	Pooled
1	No. of farmers observed	N	249	258	507
2	Intercept	a	0.85* (0.46)	1.32^{NS} (0.87)	0.12^{NS} (0.32)
3	Seed (kg)	X_1	-0.05^{NS} (0.08)	-0.25^{NS} (0.17)	-0.04^{NS} (0.07)
4	NPK (kg)	X_2	0.04^{NS} (0.03)	-0.01^{NS} (0.02)	0.00^{NS} (0.02)
5	Organic manure (kg)	X_3	-0.05^{NS} (0.06)	-0.28^{NS} (0.18)	-0.08* (0.05)
6	Plant protection chemicals (gm or ml. lit^{-1})	X_4	-0.05** (0.03)	-0.01^{NS} (0.04)	-0.03^{NS} (0.02)
7	Machine labour (hour)	X_5	0.33*** (0.05)	0.13*** (0.03)	0.23*** (0.03)
8	Bullock labour (pair hour)	X_6	-0.16*** (0.06)	0.08** (0.04)	-0.04^{NS} (0.03)
9	Human labour (man days)	X_7	0.30*** (0.07)	0.40*** (0.06)	0.41*** (0.05)
10	Dummy variable for pooled		-	-	0.34*** (0.04)
11	Coefficient of multiple determination	R^2	0.38	0.47	0.45
12	Adjusted R square	R^2	0.36	0.45	0.44
13	F value	F	20.85	31.29	51.09
14	F critical	F	2.05	2.05	1.96

Note: *, **, and *** indicate significance of values at P = 0.1, 0.05 and 0.01, respectively.

Figures in the parentheses indicate standard error of the respective coefficients.

Technology decomposition of lentil cultivators under ICARDA in West Bengal INDIA

The differences in productivity per hectare of lentil cultivation between traditional lentil growers and lentil cultivators using the improved technology and package of practices is shown in above table using the Bisaliah (1976) decomposition method of estimation. The method tries to decompose the output change resulting from technology differences and that resulting from differences in input use level. The results clearly show that technology difference has made the entire change in estimated productivity of Lentil in West Bengal India. There is a 33.36% estimated change in productivity over observed one (39.72%). Out of this 24.93% change was occurred due to technological change in Lentil cultivation in West Bengal. The change is non-neutral (exhibit +72.07%) rather than neutral (exhibit -47.13%) as the entire economy of lentil cultivation follows varying return to scale rather than constant scale of return. However substitution of inputs has played a significant part (8.42%) in the overall change of lentil productivity under ICARDA. The use of machine labour (6.99%) and bullock labour (2.77%)have shown significant positive impact on the productivity while use of surplus human labour has shown detrimental effect (-2.29%) on the overall change in productivity of lentil in the lower gangetic plains of India (Table 7).

Table 7. Technology decomposition of lentil cultivators under ICARDA in West Bengal INDIA

Serial no.	Particulars	Estimated level of change over traditional cultivation practices (%)
I	**Total observed difference in productivity**	**39.72**
II	**Sources of output growth**	
1	**Due to technology difference**	**24.93**
A	Neutral technological gap	-47.13
B	Non-neutral technological gap	72.07
2	**Gap attributable to relative change in input use level weighted by the slope coefficient of productivity function**	**8.42**
A	Seeds	-0.67
B	NPK fertilizer	0.66
C	Organic manure	-0.81
D	Plant protection chemicals	1.78
E	Machine labour	6.99

F	Bullock labour	2.77
G	Human labour	-2.29
III	**Total estimated difference in productivity (1+2)**	**33.36**
IV	**Experimental Error**	**6.36**

Socio-economic livelihood status of the lentil growers under ICARDA and traditional cultivators in West Bengal INDIA

Socio-economic livelihood status of lentil cultivators in the entire region has been evaluated and principal component analysis (PCA) method was performed to identify the component wise variability of socio-economic parameters taken under study. Nine socio-economic parameters have been taken under consideration to judge the overall livelihood status of the lentil growers. They are age of the cultivator, sex, education, caste, operational holding (ha), non-farm income, total assets of the households, gross return from crop sector and total consumption income per annum. The results showed that first three principal components (age, sex and education) have registered Eigen value greater than one with 57.37% cumulative variability of the dataset. However first four components have shown more than 10% variability of the data. So, age, sex and education level of the farmer became the prime contributor towards a sound cultivation practices as well as knowledge, perception, understanding in adopting newer technology and brings wisdom amongst the farming community. The entire community has been categorized into three distinct clusters where 89.74% farm households belong to poor socio-economic structure, 8.48% under low socio-economic structure and rest 1.78% farms has shown medium to high socio-economic livelihood status. So all over, the marginal and small farming community with operational holding less than 1.0 hectare suffers from poor and low socio-economic strata in lower gangetic plains of West Bengal India (Table 8 & 9).

Table 8. Contribution of various socio-economic components among lentil farm households in West Bengal India

Component	Eigen value	Percentage of variance	Cumulative percentage
Age	2.62	29.06	29.06
Sex	1.44	15.99	45.05
Education	1.11	12.32	57.37
Caste	0.92	10.23	67.60
Operational holding	0.79	8.81	76.41
Non-farm income	0.69	7.63	84.04
Assets	0.61	6.80	90.84
Gross return from crop	0.45	5.02	95.86
Consumption expenditure	0.37	4.14	100.00

Table 9. Socio-economic clustering of lentil farm householdsin West Bengal India

Socio-economic cluster	Poor	Low	Medium to High
Farm households	455 (89.74%)	43 (8.48%)	9 (1.78%)

Discussion

The present study confers the economic impact of lentil cultivation with improved package of practices across districts and regions of West Bengal, India. Subsequently it judges the performance of ICARDA-IFAD project on Enhancing Pulses Production for Food and Nutritional Security, Improved Livelihoods, and Sustainable Agriculture in West Bengal running since 2012-13.

ICARDA, the science for resilient livelihoods in dry areas has been working to reduce poverty and to enhance food, water and nutritional security and environmental health in the face of global challenges, including climate change around fifty countries in the world since 1975. The vision or aim is to secure and sustain the resilient livelihoods in dry areas of the developing world with adequate incomes, ready access to food, markets and nutrition and the capacity to manage nutritional resources in equitable, sustainable and more innovative ways. However, the organization is working across West Bengalconnecting more than 15000 farm households under pulse cultivation with improved package of practices and technology to enhance pulses productivity in this region and to provide their livelihood security by generating adequate level of income from pulses.

Earlier many studies have been carried out regarding economic impact of NFSM (National Food Security Mission) launched in 2009-10 in order to produce an additional 20 million tonnes of foodgrains including pulses in 17 states of the country by 2012. However the impact assessment of NFSM in eastern states of India still identifies 64% non commercial cultivators of pulses with poor fertility status of land and irrigation facilities and lower profitability (Singh and Singh 2014). The profound yield instability, lack of assured market facilities and severe disease pest infestation were listed as main reasons for shifting away from pulse cultivation in eastern India (Singh et al., 2013 and Chatterjee et. al. 2015).Availability of improved varieties, better pest management techniques, assured procurement and better market price will defiantly act as incentive for pulse cultivation across all farmers group.

The stunted progress of NFSM in implementing a sustain production level of food grain in India have been noticed where lack of adequate financial flow and thereby inadequate delivery of the physical component of production were identified as twin causes followed by lack of favourable monsoonand other weather parameters (Chatterjee and Giri 2010). So, after the failure of NFSM in promoting pulse production, ICARDA went into act in eastern India particularly in the state of West Bengal with improved package of practices and improved technology. It is the development of short-duration and heat-tolerant varieties(PM-5, Pant L-406, DPL-62, Arun, HUL 57, WBL-58, B-77) and better management that have helped in improving yields of pulses in India (Suresh and Reddy, 2013). The transformation of pulses productivity since independence (567.0 kg ha^{-1} in 1947-48 to 699.0 kg ha^{-1} in 2011-12) has not been registered remarkable while ICARDA has registered lentil yield over one ton per hectare (1060.0 kg ha^{-1}) in the state with 33.36% increase over traditional lentil growers. Technology has contributed the major part for the massive productivity gain of lentil in West Bengal. Proper land preparation and better disease pest management became the prime factor behind the enhancement of lentil productivity by ICARDA farm households and also the quality seed use with efficient labour management that could sustain the overall pulse production in West Bengal.

Policy recommendations and way forward

Pulse markets are thin and fragmented and even though the market prices are higher, the production has not increased due to lack of input investment, risky rainfed conditions, all leading to pulse crop vulnerability to biotic and abiotic stresses. In India, pulse farmers usually sell their produce to local village trader at lowest price which goes through the marketing channel to processor and ultimately to rural/urban consumer. Hence there is no marketing infrastructure for storage, warehousing, post-harvest processing and milling facilities near production centres. The disadvantages and risks involved in growing pulses are not compensated by the MSP. Price indices of lentil in India have showed higher fluctuations with overall upward trend. Thus stability in production of lentil across regions is highly needed with suitable market infrastructure. Also in West Bengal, a substantial area of lentil is sown under late sown condition in rice-fallow fields. So, early maturing varieties possessing high biomass and tolerance to high temperature at reproductive stage are required. Varieties should have resistance to diseases like stemphylum blight, rust and wilt; tolerance to low temperature at vegetative stage and high temperature at reproductive stage, and terminal soil moisture stress will be very desirable.

The scope for introduction of pulse crops in rice-fallows (mostly un-irrigated) needs to be exploited with supplemental irrigation. There is vast scope on potential expansion ofarea under fallow land in West Bengal (1.7 million ha), which is most suitable for pulses cultivation(Reddy, 2015). Some strategies and policies have already been recommended to enhance the acreage under pulse particularly in the Rice-Fallow situations. These are:

1. Identification of additional area by utilization of rice fallow lands (3 to 4 million ha) largely in Eastern India and which can yield around 2.5 million tones,

2. Diversification of about 5 lakh ha area of upland rice, 4.5 lakh ha area of millets and 3 lakh ha area under barley, mustard and wheat, currently giving low yields can be brought under kharif/ rabi pulses, (Singh *et. al.* 2016).

3. Region based recommendations of suitable lentil varieties for *paira* cropping with paddy (B-77 (Asha), B-56, K-75 (Mallika), WBL 58 (Subrata), Pant L 6, Pant L 406, Pant L 639, Subhendu(WBL 81), B-256 (Ranjan), NDL-1, WBL-77 (Moitrayee), KLS-2018, Hul-57, L-4717 (short duration)

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