TECHNICAL REPORT SUMMARY

Economic Impact Assessment of Improved Technology Adopted by Lentil Growers in West Bengal

Summary Compilation of Key Findings and Research Highlights

Photo Credit: BCKV Team (2020)

Pulses Technology Evaluations, Targeting and Policy Options for Enhanced Impact on Rural Livelihoods and Nutrition in India

Bidhan Chandra Krishi Viswavidyalaya (BCKV) Team

Soumitra Chatterjee, Rajib Nath, Kuntal Chakravarty, Sabyasachi Karak, and Soumavho Hazra

AICRP on Integrated Farming Systems - Directorate of Research - Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia-741 235 - West Bengal, India

International Center for Agricultural Research in the Dry Areas ICARDA (ICARDA) Team

Boubaker Dhehibi

Resilient Agricultural Livelihood Systems Program (RALSP) - International Center for Agricultural Research in the Dry Areas (ICARDA) – Tunis, Tunisia

JULY 2021

Table of Contents

List of Tables

List of Figures

List of Acronyms

AgeHHD	Age Household
GenderHHD	Gender Household
EducationHHD	Education Household
OccupationHHD	Occupation Household
YearFarmingHHD	Year of Farming Household (Lentil)
Familymember	Number of Family Members
DecisionHHD	Decision Maker Household
HoldingHHD	Operational size of Holding Household
AcreageLentilHHD	Acreage under Lentil
LandQuality	Land Quality
PreviousCrop	Previous season crop
FollowerCrop	Following season crop
CroppingPattern	Cropping pattern
SeedType	Seed type
CertifiedSeed	Certified seed
Variety	Variety
CollectionCentre	Collection centre
DistanceFarmHHD	Distance of market from farm household
BuySoldSeed	Buying/Selling option seed
GerminationSeed	Germination percentage of seed
SeedRate	Seed rate
OperationCost	Operational cost
ProductionLentil	Production of Lentil
ConsumptionLentil	Consumption of Lentil
MarketedLentil	Marketed Lentil
TransportationCost	Transportation cost
MiddlemanCost	Middlemen cost
AnnualExpenditureHHD	Annual expenditure of farm households
PulseIntake	Daily pulse intake by farm-family

Key Messages

Summary

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. All-over a sample of 347 farm households was surveyed in eight major lentil producing districts. There was a 36.61% estimated change in lentil productivity under ICARDA over traditional growers where the technological change has contributed 31.81% and gap due to technical substitution of input covered 4.81% change. Proper land preparation, quality seed use and better disease pest management became the prime factor behind the enhancement of lentil productivity. Overall cost benefit ratio for lentil has registered 1.25 for ICARDA and 0.74 for the traditional cultivators. Regarding varietal adoption of Lentil cultivators across various pockets of West Bengal, 29 variables have been selected purposively to judge the adoption criteria. It was observed after surveying of 135 farm households yet in the second year that the average age group of the farm-family head is between 40-60 years with education up to primary level where 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. Regarding varietal preferences and choices of lentil among the growers, majority of the farm family has adopted Moitreyee followed by Bari-7, PL-6 and HULL-57 with certified seed of germination percentage in between 71-80%. Average seed rate the farmers used to apply in the field is 31 $kgha^{1}$ with total operational cost Rs. 24,731/- per hectare. Average production in 0.19 ha of land with medium fertility status under lentil cultivation per farm was registered 181 kg where 40 kg used as their yearly consumption purposes and 141 kg sold to the local market. Average transportation cost to sell seeds is recorded Rs. 163/- with middlemen share of Rs. 249/- on an average in every time. The price was recorded Rs. 53/- per kg of seed. Each farm-family consists of five members on an average has an average annual expenditure of Rs. 57,868/- with daily intake of pulses amounting to71 $gday^{-1}family^{-1}$.

Highlights

1. Positive economic impact of ICARDA regarding introduction of improved seeds and package of practices of pulse production in West Bengal since 2012-13
2. Overall livelihood status of the Lentil farm-family has increased and ICARDA has established Long term sustainability of pulse in West Bengal
3. Technical efficiency of the farm-family has been raised with proper knowledge gaining and adoption of improved package of practices
4. Overall technological upliftment of the farm-family resulting upward shift in production frontier

Keywords

Adoption, Market development, Extent of knowledge gained, Constraints, Technological change, Marketing dynamics, Impact assessment.

1. Introduction

Lentil is one of the most nutritious cool season food legume crops in India. It occupies 1.14 million ha area with a production of 0.86 million tones and a productivity of 756.20 kg/ha (DES, Ministry of Agriculture, Govt. of India 2013-14). 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 marked lack of variability. It is grown throughout Northern and Central India mainly for grains used as traditional *Dal* (whole dehulled) as well as other culinary preparations. It contains about 25% protein, 0.7% fat, 2.1% minerals, 0.7% fiber and 59% carbohydrate. It is generally grown as rainfed crop and in West Bengal the seeds are broadcasted (as *paira* crop) in the standing crop of rice 7-10 days before harvesting (relay cropping) to capitalize the residual moisture gain and to ensure timely sowing as well as to get guarantee for germination and skipping off the tillage operations. There is tremendous potentiality of growing lentil as *paira* crop in lower Gangetic belt of West Bengal particularly in Nadia and Murshidabad district.

During independence the productivity of total pulses in India was recorded 567 kg/ha (1947-48) which was raised to 699 kg/ha in 2011-12 due to lack of availability of suitable variety seeds. Considering the importance of the crop in terms of nutritive values, the productivity must be raised to a certain extent with improved technology and improved package of practices. International Centre for Agriculture Research in the Dry Areas (ICARDA), a joint collaboration with India-Morocco Grain Legume Initiatives has already been initiated a multi-disciplinary project in order to enhance lentil productivity under rice-based cropping systems in Nadia district of West Bengal. They gave improved technology and improved package of practices to the farmers for the last three years in order to enhance lentil productivity and to meet their livelihood requirement in this region.

However, a critical evaluation is needed at a very extent to assess the technological change in lentil cultivation as well as its socio-economic impact on the farm households with improved technology and package of practices covered under the umbrella of ICARDA over the traditional lentil growers and to compare the increased livelihood status of the farmers. With this above backdrop, the study will be undergone the following definite objectives.

2. Objectives

1. Assessment of technological change and economic impact of Lentil cultivation over different agro-climatic zones of West Bengal
2. Assessment and diagnostic of lentil seeds systems and its constraints to enhance adoption.
3. Evaluation of marketing dynamics in pulses (with special emphasis in Lentils) and assessment of lentil seed sectors/system and its constraints to enhance adoption among lentil growers in the state.
4. Overall comparison of impact assessment and extent of knowledge gaining by the traditional and improved farmers under ICARDA.

3. Research Methodology

3.1. Sampling procedure

All-over a sample of 347 farm households were surveyed in eight major lentil producing districts, twenty blocks and thirty-two villages of West Bengal. They are Nadia (125 farm households), Bankura (39 farm households), Purulia (29 farm households), 24-Parganas (N) (24 farm households), Hooghly (43 farm households) and Murshidabad (24 farm households), Maldah (41 farm households), South Dinajpur (22 farm households). We have covered both ICARDA and traditional farmers to examine the economic change between them and to assess the overall impact of ICARDA in regard to adoption of improved technology in Lentil cultivation. And in the 2nd year a sample of 135 farm household were surveyed in two major lentil producing districts. They are Nadia (104 farm households) and Hooghly (31 farm households). Here we have covered ICARDA farmers to examine the lentil seeds systems and its constraints to enhance adoption.

3.2. Methodological framework year1- 2019-2020

However, a critical evaluation is needed to assess the technological change in lentil cultivation and the socio-economic impact of the improved technology and package of practices provided by ICARDA to traditional lentil growers. The livelihood status of adopter farmers needs to be compared with that of non-adopters to identify any changes. 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 (hour 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 (Bisaliah 1976) 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:

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

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

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

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).

3.2.1. 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:

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

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).

3.2.2. Statistical test – 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:

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

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.

3.2.3. Composite socio-economic score of lentil growers in Nadia district-West Bengal

Composite scoring of the status of lentil farmers using traditional and improved technologies. This has been computed using the method of composite performance indices by Lebart et al. (1984). Seven socio-economic indicators of the farm households have been taken into consideration. These are age, education level of the farmer, operational holding (ha), return from non-farm income, total assets, gross return from crop+animals, and total household consumption per annum of the 125 farm households. The methodology for computing the composite score for the individual farm household, based on the above-mentioned socio-economic indicators is cited below:

Transformation of the original variable to a new one

Let $X_{ij\#}$ denote the value of i^{th} socio-economic indicator for the j^{th} district. Then we can define a new variable, $Y_{ij\#}$, such that

$$Y_{ij\#} = \{X_{ij\#} - \underset{j}{\text{Min}}\,(X_{ij\#})\}/\{\underset{j}{\text{Max}}\,(X_{ij\#}) - \underset{j}{\text{Min}}\,(X_{ij\#})\} \qquad (1)$$

where, $\underset{j}{\text{Max}}\,(X_{ij\#})$ and $\underset{j}{\text{Min}}\,(X_{ij\#})$ are the maximum and minimum values of the i^{th} indicator for the j^{th} district. The value of the transformed variable ($Y_{ij\#}$) varies from 0 to 1. This step is followed for the other (m-1) indicators of the j^{th} district.

Step 3.2. Aggregation of the newly transformed indicators for the j^{th} district

$$Y_{meanj\#} = \sum_{i=1}^{m} w_i Y_{ij\#}$$

Where $w_i (0 < w_i < 1$ and $\sum_{i=1}^{m} w_i = 1)$

$$w_i = K/(\text{Var}\,(Y_{ij\#})), \text{ where } K = \{\sum_{i=1}^{m} \frac{1}{Var(Y_{ij\#})}\}^{-1}$$

The composite scores of seven socio-economic indicators for each farm household have been classified by the k-means cluster algorithms (Lebart et al., 1984).

K-means clustering

Computationally the k-means clustering method is analogous to an 'ANOVA in reverse'. The programme starts with k-random clusters and then joins more objects between those clusters with the goals of 1) minimizing the variability within clusters and 2) maximizing the variability between clusters. In k-means clustering, the programme tries to move objects (cases) in and out of groups (clusters) to get the most significant ANOVA results. For computing k-means clustering, the advanced SPSS+ package, k-means cluster methods, has been used (Lebert 1984).

3.3. Methodological framework year2 – 2020-2021

To cater the 2nd year analysis, village-wise descriptive statistics of various socio-economic attributes of the 347 sample farm-family has been summarized in a table followed by village-wise various input use under ICARDA and non-ICARDA farm, village-wise economic variation of lentil cultivation have been compiled and summarized in a table.

Regarding varietal adoption of Lentil cultivators across various pockets of West Bengal, 29 variables have been selected purposively to judge the adoption criteria (Table-4). ***Principal Component Analysis (PCA)*** has been performed to 22 variables out of 29 to judge the component-wise variability of the different variables owing to adoption of Lentil seeds. Components exhibits Eigen value greater than 1 are only considered and correlation matrix and component-wise matrix of eight out of 22 variables (Eigen value greater than 1) are considered.

4. Results and Discussion

The empirical findings displayed in the table below (Table 1) clearly shows that there is a huge range difference of every socio-economic aspect taken under study of sample farm households under ICARDA and traditional Lentil cultivation across villages, blocks and districts. So, variation in socio-economic livelihood status across regions is clearly shown in the study. Coefficient of variation (CV) crosses 100.0 mark in off farm income (129.91) and total assets (118.78) category of the surveyed farm households.

The results displayed in the tables 2.a and 2.b clearly tell that 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 (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. It is striking in the table that 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 it is used so unscientifically as yield is reduced to 740 kg/ha for them. Also, proper remunerative price was not obtained for the traditional farmers for their produce. The price is shown much lower (Rs. 36 per kg.) than that of average price of West Bengal (Rs. 44/-).

Table 1: Overall Socio-Economic Analysis of sample households in West Bengal

Item	Age	Sex	Education	Caste	OH (ha)	Off-Farm Income (Rs. /annum)	Total Assets (Rs. /annum)	GR from Crop+Animal (Rs. /annum)	Total Family Expenditure (Rs. /annum)
Mean	48	Male	Primary	OBC	0.88	54,100/-	15,19,398/-	1,21,951/-	95,832/-
SD	10.40	0.28	0.83	1.04	0.61	70,280	18,04,780	90,606.91	44,026
CV	21.79	25.42	35.50	34.99	69.42	129.91	118.78	74.30	45.94
Max	78	Male	Graduate	General	4.00	8,00,000/-	1,20,90,100/-	8,25,360/-	4,20,640/-
Min	20	Female	Illiterate	SC	0.10	NIL	43,000/-	13,000/-	30,560/-

Source: Own elaboration from field data (2021).

Table 2.a: Comparative study on ICARDA and traditional farm households in Lentil cultivation

Item	OH (ha)	Area under Lentil (ha)	Seed Cost (Rs. /ha)	Fert Cost (Rs. /ha)	Org Manure Cost (Rs. /ha)	PPC Cost (Rs. /ha)	Irrigation Cost (Rs. /ha)	Mach Labour Cost (Rs. /ha)	Bullock Labour Cost (Rs. /ha)
Mean Overall	0.88	0.22	2,384/-	8,567/-	768/-	4699/-	NIL	6,672/-	862/-
Mean ICARDA	0.84	0.24	2,495/-	9,464/-	873/-	3998/-	NIL	6,963/-	779/-
Mean Traditional	0.65	0.12	1,742/-	3,374/-	162/-	8758/-	NIL	4,988/-	1,343/-

Source: Own elaboration from field data (2021).

Table 2.b: Comparative study on ICARDA and traditional farm households in Lentil cultivation

Item	Human Labour Cost (Rs. /ha)	Total Operational Cost (Rs. /ha)	Yield (kg/ha)	Price (Rs. /kg)	Gross Return (Rs. /ha)	Net Return (Rs. /ha)	B:C Ratio
Mean Overall	18,066/-	42,020/-	1152.0	44/-	52,220/-	10,201/-	1.24
Mean ICARDA	18,278/-	42,851/-	1223.0	45/-	56,621/-	13,771/-	1.32
Mean Traditional	16,840/-	37,208/-	740.0	36/-	26,735/-	-10,473/-	0.71

Source: Own elaboration from field data (2021).

To undertake the economic impact assessment of Lentil cultivation in the state of West Bengal, the analysis of entire West Bengal has been done taking 292 number of farm households in which 249 farm households under ICARDA and 43 households under traditional lentil growers in the district. The outcomes are shown in the table below (Table 3).

Table 3: Geometric mean levels of productivity and input use in the cultivation of lentil using ICARDA's improved technology and following traditional growing practices (per ha) in West Bengal INDIA

Serial no.	Particulars	Lentil growers using improved technology from ICARDA	Traditional lentil growers	Change (%)
1	No. of observations	249	43	
2	Seed (kg)	34.55	32.31	6.93
3	NPK (kg)	65.44	62.52	4.67
4	Organic Manure (qtl)	8.81	9.57	-7.94
5	Plant protection (gm/ml)	133.00	136.40	-2.49
6	Machine labour (hour)	12.95	12.50	3.60
7	Bullock labour (pair hour)	6.57	7.36	-10.73
8	Human labour (days)	90.37	86.23	4.80
9	**Yield (qtl/ha)**	**10.60**	**7.08**	**49.72**

Source: Own elaboration from field data (2021).

The above table features per hectare geometric mean levels of productivity and input use for lentil crops grown under ICARDA's improved technology and package of practices and those for lentil grown following traditional cultivation practices. It is evident from the table that productivity has raised to a mammoth 49.72% over the traditional cultivators. Organic manure, plant protection chemicals and bullock labour use are much more for the traditional cultivators. It is to state that while calculating the technological impact of Lentil, we must use geometric mean instead of arithmetic mean for large number of sample households to obtain a steady mean level.

Consequently, we estimated the production function of lentil cultivation under improved technology compared with those of traditional lentil growers. The empirical findings are outlined in the table below (Table 4). The results displayed in this table identifies the production 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 with traditional cultivators as F statistics appeared to be very high (23.91) as compared to critical value (1.97). 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. In spite of applying same level of input and advised 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, 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.

Table 4: 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	43	292
2	Intercept	a	0.85* (0.46)	1.32^{NS} (2.32)	0.35^{NS} (0.42)
3	Seed (kg)	X_1	-0.05^{NS} (0.08)	-0.25^{NS} (0.45)	-0.04^{NS} (0.08)
4	NPK (kg)	X_2	0.04^{NS} (0.03)	-0.01^{NS} (0.06)	0.03^{NS} (0.03)
5	Organic manure (kg)	X_3	-0.05^{NS} (0.06)	-0.28^{NS} (0.48)	-0.06^{NS} (0.06)
6	Plant protection (gm)	X_4	-0.05** (0.03)	-0.01^{NS} (0.10)	-0.05* (0.03)
7	Machine labour (hour)	X_5	0.33*** (0.05)	0.13^{NS} (0.09)	0.31*** (0.05)
8	Bullock labour (pair hour)	X_6	-0.16*** (0.06)	0.08^{NS} (0.11)	-0.12** (0.05)
9	Human labour (man days)	X_7	0.30*** (0.07)	0.40** (0.17)	0.35*** (0.06)
10	Dummy variable for pooled				0.29*** (0.08)
11	Coefficient of multiple determination	R^2	0.38	0.47	0.40
12	Adjusted R square	R^2	0.36	0.36	0.39
13	F value	F	20.85	4.38	23.91
14	F critical	F	2.05	2.29	1.97

Source: Own elaboration from field data (2021).
*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.

The decomposition analysis of total change in input use and output produced per hectare of lentil cultivation between lentil growers using ICARDA's improved technology and traditional lentil growers in Nadia district West Bengal INDIA are undertaken and the empirical findings are outlined in the table below (Table 5).

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 Nadia district of West Bengal India. There is a 36.61% estimated change in productivity over observed one (49.72%). Out of this 31.81% change was happened due to technology in Lentil cultivation in West Bengal. The change is non-neutral (exhibit +78.94%) rather than neutral (exhibit -47.13%) as the entire economy of lentil cultivation follows varying return to scale rather than constant scale of return. The use machine labour and human labour in lentil cultivation has shown significant positive change over traditional cultivators in West Bengal.

Table 5: Decomposition analysis of total change in input use and output produced per hectare of lentil cultivation between lentil growers using ICARDA's improved technology and traditional lentil growers in West Bengal INDIA

Serial no.	Particulars	New technology and traditional practice (%)
I	**Total observed difference in productivity**	**49.72**
II	**Sources of output growth**	
1	**Due to technology difference**	**31.81**
A	Neutral technological gap	-47.13
B	Non-neutral technological gap	78.94
2	**Gap attributable to relative change in input use level weighted by the slope coefficient of productivity function**	**4.81**
A	Seeds	-0.32
B	NPK fertilizer	0.19
C	Organic manure	0.39
D	Plant protection chemicals	0.13
E	Mech. labour	1.16
F	Bullock labour	1.87
G	Human labour	1.39
III	**Total estimated difference in productivity (1+2)**	**36.61**

Source: Own elaboration from field data (2021).

The composite socio-economic scoring of Lentil cultivators has been performed using seven major parameters (Age, Education, Operational Holding (ha), non-farm income, Total Assets, Total return and Total consumption expenditure). Based on those parameters the score was 0.16 ranges a huge from 0.75 to 0.07, showing a very poor condition of their livelihoods. These can be put into 4 distinct clusters (High, Medium, Low and Poor) showing different class of status (Table 6).

Table 6: Composite socio-economic scoring of lentil growers in Nadia district, West Bengal

Category	No. of observations	Maximum score	Minimum score	Average score
ICARDA	249	0.75	0.07	0.16
Traditional	43	0.25	0.07	0.13
Pooled	**292**	**0.75**	**0.07**	**0.16**

Source: Own elaboration from field data (2021).

The cluster membership analysis of lentil cultivators following ICARDA practices and those following traditional methods reveals that majority (96.0%) of the farm households belong to low and poor socio-economic status followed by 12 farm households are under medium category and only one have higher socio-economic status (Tables 7.a and 7.b).

Table 7.a: Final Cluster Centers

	Cluster			
	High	**Low**	**Medium**	**Poor**
VAR	.75	.20	.38	.12

Source: Own elaboration from field data (2021).

Table 7.b. Cluster category and frequency of farm households

Cluster category	Frequency of farm households
Cluster 1 (High)	1 (0.34%)
Cluster 2 (Low)	94 (32.19%)
Cluster 3 (Medium)	12 (4.11%)
Cluster 4 (Poor)	185 (63.36%)
Total	**292 (100.00%)**

Source: Own elaboration from field data (2021).

Note: Figure in parentheses is the proportion of the total households surveyed (%)

Finally, F tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal (Table 8).

Table 8: ANOVA statistical F-test

	Cluster		Error			
	Mean Square	**df**	**Mean Square**	**df**	**F**	**Sig.**
VAR	.476	3	.001	288	488.802	.000

Source: Own elaboration from field data (2021).

In the second project cycle 2020-2020, we the district, block and village-wise socio-economic livelihood status analysis of lentil cultivators in west Bengal (based on Primary Data collected from sample surveyed farm households from Northern and Southern Bengal) has been undertaken. During this cycle, we have managed to cover the pending North Bengal districts (Maldah and Dakshin Dinajpur) under UBKV-ICARDA scheme in 2020-21 season and allover a total sample of 347 farm households were fully surveyed in eight major lentil producing districts, twenty blocks and thirty-two villages of entire West Bengal. They are Nadia (125 farm households), Bankura (39 farm households), Purulia (29 farm households), 24-Parganas (North) (24 farm households), Hooghly (43 farm households), Murshidabad (24 farm households), Maldah (41 farm households) and South Dinajpur (22 farm households). We have covered both ICARDA and traditional farmers to examine the economic change between them and to assess the overall impact of ICARDA in regard to adoption of improved technology in Lentil cultivation.

Tables A1-A7 represents the socio-economic background of the sample farm households followed by the differences in economic impact of improved Lentil cultivation across districts blocks and villages of West Bengal. All over, a 347 number of marginal and small sample farm households were covered entirely across the state where 44 farm households possess traditional method of cultivation and 303 farm households possess improved technological practices under ICARDA. The average age of the cultivators is between 45-50 years with their educational background up to primary level. Most of the farm households belong to backward caste. Regarding operational holding, there is a vast difference observed between traditional and improved farm households under lentil where average traditional farm households possess 0.69 ha of land and farm households under ICARDA possess 0.93 ha of land with an overall possession of 0.90 ha of land under cultivation. Almost all the farmers belong to farming community have their non-farm income around Rs. 50,000/- per annum working as hired seasonal labourer. Everyone possesses their own land and dwelling houses with common agricultural machinaries like shallow pump and various household equipment's and also possesses livestock. An average valuation of total assets of an individual farm household mounted to Rs. 18, 42,302/- per households including their land and dwelling house. Average gross return obtained per household per annum from all crops and livestock has varied for traditional and ICARDA farm households where the amount is Rs. 99,990/- for the traditional farm households and Rs. 1, 12,157/- for the ICARDA farms. ICARDA farmers expends more than they received from the return from crop and animal while the total return obtained from farm and non-farm sources surpass the expenditure of the farm per annum.

Regarding village-wise comparison in input use of Lentil, traditional cultivators have used 32.25 kg of seed per hectare while the highest percent increase in seed use was recorded in Kota village Goghat-I block Hooghly district with 60 kg seed use (88.25 p.c. more than the traditional cultivators). It may be due to the variation in the measurement of land that varies region after region. Lowest input use was found in Sirishnagar village Jiagung, Murshidabad district with 17.05 kg per ha (47.14 p.c. less than the traditional cultivation practices). Regarding NPK use in both inorganic and organic sources, highest NPK consumption in lentil cultivation by ICARDA was found in Ichhapur village, Bolagarh, Hooghly district with 284.39 p.c. increase over the traditional practices. Most of the areas have not used any organic sources of manure and fertilizer in Lentil while the highest intake under ICARDA farm was recorded in Danapul village, Habra-I block 24-Parganas (N). Farmers were hardly using any insecticides in Lentil field while the highest use of insecticides in Lentil was observed in Basulibandh

village, Chhatna block, Bankura (7.50 g/ml per lit per hectare). Average irrigation hour has been recorded 7.50 hours for ICARDA farms where it was 7.62 hours for the traditional farms. 8.93 hours of machine labour has been used by traditional lentil cultivators while highest machine labour was utilized in Muktarpur village, Hooghly (19.40 hours). Bullock labour was hardly used in any regions but Bankura Purulia district have still used bullock labour for land preparation instead of Farm Machinaries. Beliapukur in Murshidabad and Lachmanpur village, Gangajalghati, Bankura has registered the highest bullock labour use (21.61 hours and 20.33 hours per hectare). Human labour use was registered highest in Ichhapur village, Bolagarh, Hooghly with 187.50 man-days per hectare while the traditional cultivators have used much less manpower to cater the entire operation (84.07 man-days per hectare). Productivity of lentil has been varied a lot from region to region with a maximum of 2140 kg per hectare to a minimum 232 kg per hectare. Barring few pockets, it surpasses the traditional productivity of Lentil (681 kg per hectare) in most of the regions of the state. It proves that ICARDA has provided improved seed as well as improved package of practices for Lentil over districts and regions of West Bengal which enhance the overall productivity of the crop (Table-A2).

Regarding Village-wise comparative economics of Lentil cultivation, the average area under Lentil was recorded 0.24 ha for ICARDA farms whereas it was 0.12 ha for the traditional farm. Operational cost per hectare was quite high for the ICARDA farms while the return obtained from one hectare of land is of much difference for the ICARDA farms. Traditional farms face losses due to poor management practices and return per rupee of investment comes below one for them. ICARDA farms have B: C ratio greater than one (1.25) when considering all farms. It was quite remarkable in Sirishnagar Murshidabad (3.91) and also for Goghat-I block of Muktarpur village (2.81) proves the better management practices of Lentil under ICARDA (Table-A3).

Regarding varietal adoption of Lentil cultivators across various pockets of West Bengal, 29 variables have been selected purposively to judge the adoption criteria. It was observed after surveying of 135 farm households yet in the second year that the average age group of the farm-family head is between 40-60 years with education up to primary level. Almost all family is dependent on farming as the major occupation across districts and regions. Average farming experience under ICARDA scheme is of 3 years and each farm-family consists of an average family member of 5. All sorts of varietal adoption decision is taken by the head of the family that is the farmer himself with an utilization of 0.19 ha of land under Lentil though their average size of holding is 0.85 ha. Almost a medium land quality and fertility status prevailed across various zones of West Bengal for Lentil cultivation. Farmers usually follow Rice-Lentil cropping sequence as paddy is the major staple food crop of India. In West Bengal Lentil has usually grown as *paira* crop after paddy and seed are sown immediately before 7-10 days of harvest of rainfed paddy as relay crop to capture the residual moisture of the soil. Almost all the farm households have used improved certified lentil seed from ICARDA. Regarding varietal preferences and choices of lentil among the growers, majority of the farm family has adopted Moitreyee followed by Bari-7, PL-6 and HULL-57. The seeds are collected from the dealers registered for the ICARDA-IFAD programme; the outlets are between 1 to 2 km from the farm with 71-80% germination percentage. Average seed rate the farmers used to apply in the field is 31 kgha[1] with total operational cost Rs. 24,731/- per hectare. Average production in 0.19 ha of land under lentil cultivation per farm was registered 181 kg where 40 kg used as their yearly consumption purposes and 141 kg sold to the local market. Average transportation cost to sell seeds is recorded Rs. 163/- with middlemen share of Rs. 249/- on an average in every time. The price was

recorded Rs. 53/- per kg of seed. Each farm-family has an average annual expenditure of Rs. 57,868/- with daily intake of pulses amounting to71 $gday^{-1}family^{-1}$.

While again considering the 22 variables out of 29, to judge the overall adoption criteria, the correlation matrix has shown that barring few cases, there are a very low level of interdependency among the explanatory variables that is there is no significant level of autocorrelation exists and all the variables show independency to judge the adoption variability of the Lentil growers across the states and regions (Table-A5).

The component-wise analysis of different variables has shown that first eight components with Eigen-value greater than 1 have explained 70.67% cumulative variability to the overall adoption of the lentil growers. So, these eight components are taken to be in consideration as the key components to judge adoption. Component-wise matrices have registered that production of lentil and its quantity sold become the highest positive significant factors defined in Component 1 (22.73% variability). However, number of farm-family member and their daily intake has shown significantly negative scores in Component 2 (10.82% variability). Varietal preferences as well as distance covered to avail it became the most significant positive factors explained in Component 3 (8.76% variability). Average year of Farming Experience followed by Operational Holding became the significant negative effect in Component 4 (7.32% variability). Land Quality and fertility became the prime contributing factor in Component 5 (5.78% variability). Crop grown just before Lentil along with seed rate and quantity consumed became the significant strong factor contributor in Component 6 (5.47% variability). Farming experience and operational cost became the significant contributor in Component 7 while farmers, overall education and knowledge became the prime contributor in Component 8 (4.87% variability). So, overall component-wise variability of factors contributor is shown in the findings (Table-A6 and A7).

We have only covered 135 farm-households for the second-year work and yet to cover the market dynamics of Lentil due to pandemic Covid-19 situation in West Bengal. We hope to cater as many as farm-family as we can in the present year and also the Market.

5. Concluding Remarks and Policy Implications

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 of area 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 tone.
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).

6. Acknowledgments

This work was undertaken as part of the "*Pulses Technology Evaluations, Targeting and Policy Options for Enhanced Impact on Rural Livelihoods and Nutrition in India*" project funded by the Indian Council of Agricultural Research – Indian Ministry of Agriculture and Framers Welfare (https://icar.org.in/) under a grant agreement with the International Center for Agricultural Research in the Dry Areas (ICARDA - http://www.icarda.org) within the framework of the CGIAR Research Program on Grain Legumes and Dryland Cereals (http://gldc.cgiar.org/). The authors would also like to thank the Bidhan Chandra Krishi Viswavidyalaya - BCKV (https://www.bckv.edu.in/) socio-economic and technical teams for their devotion and commitment to implementing this work. Finally, farmers' contribution is acknowledged; they are essential partners who provided vital information necessary for this study.

The views expressed are the authors' own and do not necessarily reflect ICARDA, ICAR, BCKV, GLDC, CGIAR or any involved research and development partners in this research program. Personal information including Name, Business Title, Email, Phones, Images and GPS points included in this report have been authorized in writing or verbally by the data subject.

7. References

Anonymous 2013-14 Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India

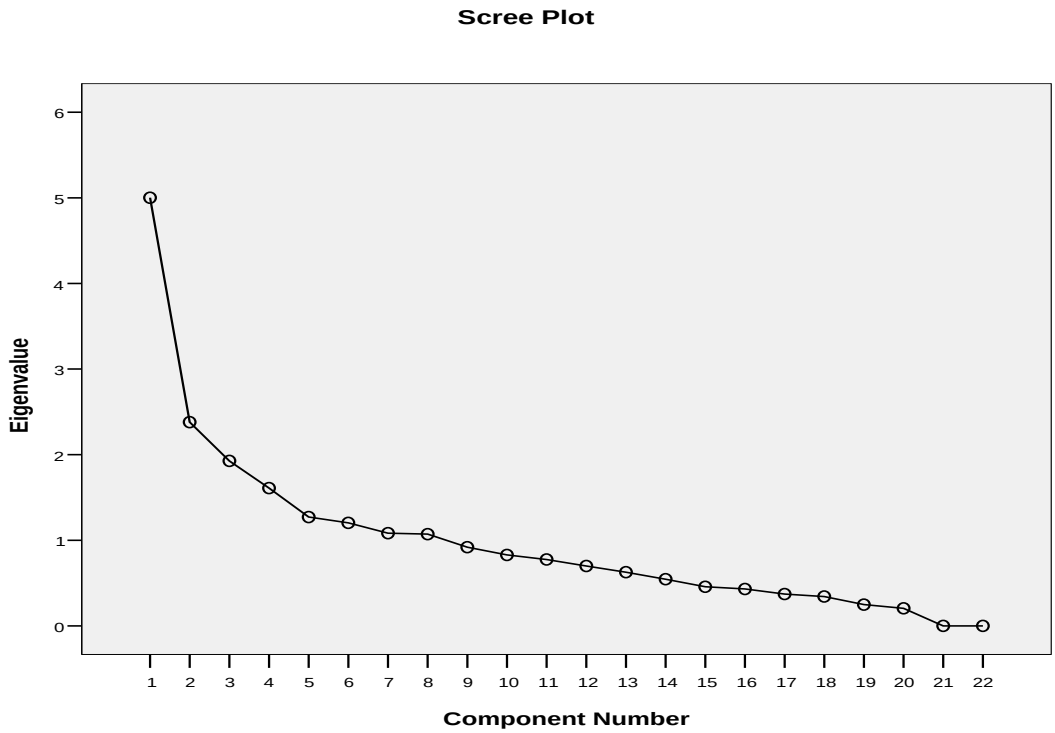
Bisaliah, S.1976. Effect of technological change on output, employment and functional income distribution in Indian agriculture: a case study of the Punjab wheat economy. Ph.D. Thesis, Univ. Microfilms International, Ann Arbor, Michigan, UDA.https://shodhganga.inflibnet.ac.in/bitstream/10603/173631/10/09_chapter%202.pdf

Ludovic Lebart, Alain Marineau & Kenneth M. Warwick (1984). *Multivariate Descriptive Statistical Analysis*, pp. 118-119.

Reddy, A A. 2015. Pulses Production Trends and Strategies to become self-sufficient. Indian Farming 65 (6): 02– 10.https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2723049

Singh, P, B Shahi, and K M Singh. 2016. Trends of Pulses Production, Consumption and Import in India: Current Scenario and Strategies. SSRN Electronic Journal.https://ssrn.com/abstract=2907228.

Figure 1: Scree plot.



Source: Own elaboration from field data (2021).

Annexes

Village Block District Level Socio-Economic Profile Analysis of Sample Surveyed Households

Table-A1: Village-wise Descriptive Statistics of the surveyed Lentil growers

Types	Village	Block	District	Number of Farm Households	Age (yrs)	Sex	Education	Caste	Total OH (ha)	Non-Farm Income (Rs./annum)	Total Assets (Rs.)	GR from Crop+Livestock (Rs./annum)	Gross Expenditure Family (Rs./annum)
Traditional				**44**	**46±10.28**	**1±0.32**	**2±0.78**	**3±0.84**	**0.69±0.45**	**53052±42283**	**1119891±861109**	**99989±38695**	**82024±31444**
ICARDA	Panpur-Jahirapara	Haringhata	Nadia	22	53±10.61	1±0.00	3±0.94	3±0.68	0.86±0.55	74364±69830	2852777±2862935	205280±150885	103012±22744
	Bizra			16	48±9.14	1±0.25	3±0.58	4±0.00	0.76±0.28	68938±35995	987024±445963	139119±30809	108249±11183
	Kurumbelia			21	56±8.82	1±0.00	2±0.85	3±0.22	0.70±0.40	71298±28695	1965490±1859367	183393±58186	100788±14901
	Dhakalipara	Mollabelia		6	53±10.68	1±0.00	3±0.41	3±1.17	1.20±0.91	120667±79445	4234137±2386189	158729±34122	110027±47222
	Chapra	Ranaghat-II		7	37±9.53	1±0.00	2±1.29	4±0.49	0.78±0.34	158857±110145	6034143±2590002	160275±52423	137086±30751
	Atilia	Chakdaha		8	60±7.64	1±0.00	3±0.83	4±1.06	1.24±0.70	117250±104875	3371215±1339573	145949±56446	89565±32628
	Harekrishnapur	Karimpur		11	57±8.15	1±0.00	2±1.10	2±1.30	0.61±0.30	59455±15129	3139149±3065391	131632±46673	91763±50840
	Danapul	Habra-I	24-Parganas (North)	14	44±2.43	1±0.00	3±0.00	3±1.41	1.04±0.42	23357±6879	649186±266704	105293±43178	86150±8200
	DakkhinBaidyapur	Barasat-II		10	54±8.55	1±0.00	2±0.82	4±0.32	0.70±0.53	42450±44148	1073504±1036075	76946±40283	121160±31493
	Dahala	Khatra	Bankura	15	48±4.62	1±0.00	3±0.46	3±0.65	1.06±0.73	60933±15252	933717±581901	82267±54867	74129±44667
	Lachmanpur	Gangajalghati		8	41±4.78	1±0.52	3±0.46	3±1.60	1.34±0.64	21250±7246	791310±418382	111176±56179	56205±9076
	Basulibandh	Chhatna		6	43±2.80	1±0.00	2±0.41	2±0.41	1.31±1.32	23750±8036	689908±782720	103763±104730	62085±10243
	Bilbarda	Taldangra		7	42±2.06	1±0.00	2±0.49	3±1.46	0.76±0.20	13486±3544	430700±102144	76107±22459	65777±11512
	Raghunathpur	Raghunathpur	Purulia	9	43±2.24	1±0.00	2±0.83	3±0.50	0.79±0.20	10544±2018	361688±92222	72156±21381	53184±4989
	Kushtanr	Jhalda		4	42±3.10	1±0.50	3±0.50	3±0.50	0.48±0.10	8125±1750	246903±41923	48350±9469	53205±4036
	Malthol	Purulia-II		10	36±2.91	2±0.32	2±0.32	3±0.63	0.69±0.14	12150±3424	373920±69425	68361±15116	59154±6894
	Sirishnagar	Jiaganj	Murshidabad	14	45±10.69	1±0.36	3±0.63	4±0.00	0.88±0.78	5500±6226	1689496±1487537	79251±22124	100737±14782
	Beliapukur	Bhagawangola		10	43±7.63	1±0.52	2±0.82	1±0.95	0.58±0.31	8950±2101	1101510±588065	64921±13502	93930±8352
	Icchapur	Bolagarh	Hooghly	8	56±8.05	1±0.35	3±0.53	4±0.00	1.59±0.69	3375±2560	1404000±1153130	77495±24405	115107±22997
	Muktarpur	Goghat-I		16	45±13.25	1±0.00	1±0.51	2±0.54	0.57±0.31	71113±68086	939331±456778	109116±48811	107684±37767
	Kota			19	52±11.97	1±0.00	2±0.58	2±0.76	1.33±0.64	81895±176109	732947±875535	146419±114679	171602±100607
	Kalinagar	Gajol	Malda	22	51±12.25	1±0.00	3±1.01	1±0.00	1.43±0.68	53000±69700	3281453±1970710	147749±106100	153466±50020
	Maniknagar	Chanchol-II		18	46±13.73	1±0.00	2±0.81	3±0.77	0.67±0.61	27528±50426	2692456±2366530	58973±58599	130644±51502
	Nakoir Tedrail Malancha Dhanail Lalpur Phulbari Deudhara Mahanpur	Gangarampur Hili	Dinajpur (South)	22	48±12.02	1±0.00	3±1.10	2±0.96	0.90±0.59	43818±66579	4101041±2382348	19693±31037	241828±227082
ICARDA				**303**	**48±10.81**	**1±0.25**	**2±0.86**	**3±1.12**	**0.93±0.62**	**51150±71763**	**1947207±2117479**	**112157±84704**	**115042±84589**
GRAND TOTAL				**347**	**48±10.75**	**1±0.26**	**2±0.86**	**3±1.10**	**0.90±0.60**	**51391±68685**	**1842302±2020319**	**110614±80405**	**110855±80556**

Source: Own elaboration from field data (2021).

Note: Mean ± SD

Sex: Male = 1 Female = 2, Education: Illiterate = 1 Up to Primary = 2 High School = 3 Graduation and above = 4, Caste: Schedule Caste = 1 Schedule Tribe = 2 OBC = 3 General = 4 Others = 5

Table-A2: Village-wise Economic impact of Lentil cultivation on ICARDA farm households (Hectare)

Village	Seed (kg)	NPK_IS (kg-nutrient)	NPK_OS (kg-nutrient)	Insecticides (gm/ml lit^{-1})	Irrigation (hour)	Machine Labour (hour)	Bullock Labour (pair-hour)	Human Labour (man-days)	Yield (kg)
Panpur-Jahirapara									
Bizra	33.75 (4.66)	35.85 (-37.38)	1.52 (-18.17)	1.15 (5.25)	7.50 (-1.56)	6.75 (-24.38)	7.50 (-23.40)	45.57 (-45.79)	919.67 (34.95)
Kurumbelia	27.90 (-13.50)	69.81 (21.92)	1.52 (-18.17)	2.27 (106.96)	7.50 (-1.56)	6.59 (-26.27)	16.48 (68.29)	92.22 (9.70)	1056.52 (55.03)
Dhakalipara	18.90 (-41.40)	82.02 (43.25)	2.09 (12.86)	1.67 (51.79)	7.50 (-1.56)	17.17 (92.23)	6.68 (-31.76)	104.14 (23.88)	796.99 (16.95)
Chapra	31.97 (-0.86)	83.05 (45.05)	1.52 (-18.17)	0.94 (-13.99)	7.50 (-1.56)	8.28 (-7.30)	7.50 (-23.40)	81.52 (-3.03)	1836.34 (169.47)
Atilia	39.57 (22.68)	64.30 (12.30)	2.80 (51.39)	0.75 (-31.66)	7.50 (-1.56)	16.01 (79.28)	7.50 (-23.40)	70.39 (-16.27)	783.55 (14.98)
Harekrishnapur	40.93 (26.92)	73.51 (28.39)	2.37 (28.00)	0.92 (-16.54)	7.50 (-1.56)	17.38 (94.61)	7.50 (-23.40)	62.58 (-25.55)	925.55 (35.82)
Danapul	36.92 (14.49)	82.64 (44.33)	27.97 (1410.48)	0.75 (-31.66)	7.50 (-1.56)	9.22 (3.22)	11.14 (13.82)	81.24 (-3.36)	990.62 (45.37)
DakkhinBaidyapur	20.19 (-37.39)	46.50 (-18.79)	1.52 (-18.17)	0.75 (-31.66)	7.50 (-1.56)	15.00 (67.93)	7.50 (-23.40)	93.20 (10.86)	1000.19 (46.77)
Dahala	29.87 (-7.38)	70.81 (23.67)	17.79 (860.98)	1.57 (43.15)	7.50 (-1.56)	8.75 (-2.02)	9.09 (-7.13)	45.14 (-46.30)	715.58 (5.00)
Lachmanpur	33.92 (5.17)	21.91 (-61.73)	9.62 (419.32)	0.75 (-31.66)	7.50 (-1.56)	15.00 (67.93)	20.33 (107.64)	80.31 (-4.47)	1320.29 (93.74)
Basulibandh	30.00 (-6.98)	92.77 (62.02)	9.62 (419.32)	7.50 (583.45)	7.50 (-1.56)	7.50 (-16.04)	7.50 (-23.40)	150.00 (78.43)	751.71 (10.31)
Bilbarda	30.00 (-6.98)	31.07 (-45.73)	9.43 (409.47)	0.75 (-31.66)	7.50 (-1.56)	5.57 (-37.61)	7.50 (-23.40)	34.12 (-59.41)	423.73 (-37.82)
Raghunathpur	30.00 (-6.98)	10.23 (-82.14)	1.52 (-18.17)	1.07 (-2.27)	7.50 (-1.56)	11.02 (23.41)	7.50 (-23.40)	60.06 (-28.55)	609.60 (-10.55)
Kushtanr	27.92 (-13.44)	55.30 (-3.42)	1.52 (-18.17)	0.75 (-31.66)	7.50 (-1.56)	15.00 (67.93)	7.50 (-23.40)	64.88 (-22.82)	723.09 (6.11)
Malthol	30.00 (-6.98)	51.55 (-9.98)	1.52 (-18.17)	0.75 (-31.66)	7.50 (-1.56)	15.00 (67.93)	7.50 (-23.40)	70.97 (-15.57)	821.14 (20.50)
Sirishnagar	17.05 (-47.14)	18.80 (-67.17)	1.52 (-18.17)	0.75 (-31.66)	7.50 (-1.56)	17.40 (94.82)	7.50 (-23.40)	70.34 (-16.32)	1770.80 (159.85)
Beliapukur	47.76 (48.10)	10.44 (-81.77)	1.52 (-18.17)	0.86 (-21.49)	7.50 (-1.56)	4.49 (-49.78)	21.61 (120.66)	41.08 (-51.13)	232.23 (-65.92)
Icchapur	27.29 (-15.39)	220.09 (284.39)	1.52 (-18.17)	0.75 (-31.66)	7.50 (-1.56)	12.61 (41.21)	7.50 (-23.40)	187.50 (123.04)	435.41 (-36.11)
Muktarpur	58.99 (82.92)	76.21 (33.10)	1.06 (-42.79)	0.83 (-24.42)	7.50 (-1.56)	19.40 (117.13)	7.50 (-23.40)	132.90 (58.09)	2139.54 (213.96)
Kota	60.71 (88.25)	43.25 (-24.47)	1.52 (-18.17)	4.95 (350.64)	7.50 (-1.56)	14.46 (61.91)	7.50 (-23.40)	116.41 (38.48)	1989.80 (191.99)
Kalinagar	30.00 (-6.98)	135.47 (136.60)	2.51 (35.45)	0.19 (-82.54)	8.51 (11.66)	10.28 (15.06)	7.50 (-23.40)	156.46 (86.12)	1058.83 (55.37)
Maniknagar	30.00 (-6.98)	160.83 (180.88)	3.82 (106.14)	1.69 (53.59)	9.09 (19.34)	7.50 (-16.04)	7.50 (-23.40)	119.39 (42.03)	960.16 (40.90)
Nakoir Tedrail Malancha Dhanail Lalpur Phulbari Deudhara Mahanpur	30.00 (-6.98)	154.20 (169.31)	1.52 (-18.17)	13.73 (1151.00)	7.50 (-1.56)	7.50 (-16.04)	7.50 (-23.40)	132.31 (57.39)	1107.75 (62.55)
Traditional	32.25	57.26	1.85	1.10	7.62	8.93	9.79	84.07	681.47

Source: Own elaboration from field data (2021).

Figures represent geometric mean level of input use

Figures in the parentheses represent percent change over traditional lentil cultivators

Table-A3: Village-wise Average Comparative Economics of Lentil cultivation among small and marginal farm households in West Bengal

Village	Area under LENTIL (ha)	Operational Cost (Rs. ha^{-1})	Gross Return (Rs. ha^{-1})	Net Return (Rs. ha^{-1})	Return per rupee of investment
Panpur-Jahirapara	0.14	57678	58345	(+)667	1.01
Bizra	0.20	25868	44719	(+)18850	1.73
Kurumbelia	0.12	66059	49268	(-)16791	0.75
Dhakalipara	0.23	49556	54125	(+)4569	1.09
Chapra	0.21	27567	98304	(+)70737	3.57
Atilia	0.15	35019	34406	(-)613	0.98
Harekrishnapur	0.12	36629	40534	(+)3905	1.11
Danapul	0.26	62093	45348	(-)16745	0.73
DakkhinBaidyapur	0.18	37564	64238	(+)26674	1.71
Dahala	0.18	22094	26516	(+)4422	1.20
Lachmanpur	0.16	33234	47981	(+)14747	1.44
Basulibandh	0.10	39631	38125	(-)1506	0.96
Bilbarda	0.12	16771	16661	(-)110	0.99
Raghunathpur	0.13	28433	27750	(-)683	0.98
Kushtanr	0.12	27094	28500	(+)1406	1.05
Malthol	0.12	28039	33300	(+)5261	1.19
Sirishnagar	0.27	21865	85479	(+)63613	3.91
Beliapukur	0.05	50874	14006	(-)36868	0.28
Icchapur	0.40	52069	21478	(-)30591	0.41
Muktarpur	0.40	48114	135023	(+)86909	2.81
Kota	0.53	53988	95945	(+)41957	1.78
Kalinagar	0.38	68206	59482	(-)8724	0.87
Maniknagar	0.32	57462	56758	(-)703	0.99
Nakoir, Tedrail, Malancha, Dhanail Lalpur, Phulbari, Deudhara, Mahanpur	0.34	57566	74898	(+)17332	1.30
ICARDA Overall	**0.24**	**45920**	**57223**	**(+)11303**	**1.25**
Traditional	**0.12**	**38103**	**28122**	**(-)9981**	**0.74**

Source: Own elaboration from field data (2021).

Table-A4: Adoption variables of Lentil growers in West Bengal

Serial No.	Acronym	id	Unit
1	AgeHHD	AGE	Code (20-40 yrs. = 1, 40-60 yrs. = 2, Above 60 yrs. = 3)
2	GenderHHD	SEX	Code (Male = 1, Female = 2)
3	EducationHHD	EDUCATION	Code (Illiterate = 1, Up to primary = 2, High school = 3, Graduate = 4)
4	OccupationHHD	OCCUPATION	Code (Farming = 1, Others = 2)
5	YearFarmingHHD	FARM_EXP (ICARDA)	Years
6	Familymember	TOT_FAMILY	Number
7	DecisionHHD	VAR_DEC	Code (Male = 1 Female = 2)
8	HoldingHHD	OH	Ha
9	AcreageLentilHHD	ACREAGE_LENTIL	Ha
10	LandQuality	LQ	Code (Good = 1, Average = 2, Bad = 3)
11	PreviousCrop	PCROP	Code (Lentil = 1, Rice = 2, Others = 3)
12	FollowerCrop	FCROP	Code (Lentil = 1, Rice = 2, Others = 3)
13	CroppingPattern	CROPPING_PATTERN	Code (Relay =1, Sole = 2, Intercropping = 3, Others=4)
14	SeedType	SEED_TYPE	Code (Local = 1, Improved = 2, HYV = 3)
15	CertifiedSeed	CERTIFIED_SEED	Code (Yes = 1, No = 0)
16	Variety	VARIETY	Code (Moitreyee = 1, HuLL-57 = 2, PL-6 = 3, Bari-7 = 4)
17	CollectionCentre	COLLEC_CENTRE	Code (ICARDA = 1, Local = 2, Dealer = 3, Distributor = 4)
18	DistanceFarmHHD	DISTANCE	Code (Less than 1 km = 4, 1km. to 2 km. = 3, 3km to 4 km = 2, More than 5km. = 1)
19	BuySoldSeed	PURCHASE	Code (Yes = 1, No = 0)
20	GerminationSeed	GERMINATION	Code (60-70% = 1, 71-80% = 2, 81-90% = 3)
21	SeedRate	SEED_RATE	Kg/ha
22	OperationCost	TOT_OC	Rs/ha
23	ProductionLentil	PROD	Kg
24	ConsumptionLentil	QTY_CONSUMED	Kg
25	MarketedLentil	QTY_SOLD	Kg
26	TransportationCost	TRANSPORT	Rs

27	MiddlemanCost	MIDDLEMEN	Rs
28	AnnualExpenditureHHD	TOT_EXP	Rs/annum
29	PulseIntake	DAILY_INTAKE_PULSE	g/day/family

Source: Own elaboration from field data (2021).

Table-A5: Correlation Matrix of various socio-economic factors affecting adoption of Lentil

Parameters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22
X1	1.000	.007	-.184	-.024	-.081	.192	.184	.091	.196	.248	-.145	.123	.035	.157	.089	.268	-.019	.265	-.123	.215	-.172	-.024
X2	.007	1.000	-.040	-.012	-.136	-.049	-.097	.040	-.178	.005	.070	-.032	-.095	-.043	-.075	-.187	-.087	-.175	-.006	-.241	.133	-.012
X3	-.184	-.040	1.000	.115	.162	-.011	-.124	.133	-.036	-.140	-.019	-.015	-.109	-.145	-.104	-.088	.021	-.089	.006	-.071	.000	.115
X4	-.024	-.012	.115	1.000	.080	.321	-.299	-.056	.311	-.003	-.177	-.044	.044	.003	.050	.315	-.077	.318	-.242	.111	.062	1.000
X5	-.081	-.136	.162	.080	1.000	.326	-.160	.115	.213	-.111	-.007	.027	.208	-.079	-.092	.136	-.026	.137	-.018	.167	-.026	.080
X6	.192	-.049	-.011	.321	.326	1.000	-.233	-.079	.419	.080	-.189	.129	.286	-.005	.188	.564	-.044	.559	-.474	.362	-.038	.321
X7	.184	-.097	-.124	-.299	-.160	-.233	1.000	-.126	-.187	.098	.070	.094	-.010	-.043	.054	-.078	.054	-.082	.180	.290	-.173	-.299
X8	.091	.040	.133	-.056	.115	-.079	-.126	1.000	.002	-.167	-.115	-.057	-.090	.024	-.108	-.152	.024	-.152	.157	-.132	-.072	-.056
X9	.196	-.178	-.036	.311	.213	.419	-.187	.002	1.000	.152	-.589	.003	.373	.008	-.092	.623	-.177	.631	-.376	.456	-.343	.311
X10	.248	.005	-.140	-.003	-.111	.080	.098	-.167	.152	1.000	-.136	.027	.120	.068	.031	.206	-.107	.214	-.036	.161	-.046	-.003
X11	-.145	.070	-.019	-.177	-.007	-.189	.070	-.115	-.589	-.136	1.000	.380	-.029	-.093	.007	-.305	.273	-.329	.065	-.251	.271	-.177
X12	.123	-.032	-.015	-.044	.027	.129	.094	-.057	.003	.027	.380	1.000	.257	-.159	.127	.247	.356	.205	-.231	.270	-.040	-.044
X13	.035	-.095	-.109	.044	.208	.286	-.010	-.090	.373	.120	-.029	.257	1.000	.030	-.091	.514	-.017	.507	-.311	.369	-.264	.044
X14	.157	-.043	-.145	.003	-.079	-.005	-.043	.024	.008	.068	-.093	-.159	.030	1.000	-.085	-.044	.067	-.050	-.075	-.097	.052	.003
X15	.089	-.075	-.104	.050	-.092	.188	.054	-.108	-.092	.031	.007	.127	-.091	-.085	1.000	.183	.128	.166	-.105	.213	.180	.050
X16	.268	-.187	-.088	.315	.136	.564	-.078	-.152	.623	.206	-.305	.247	.514	-.044	.183	1.000	-.110	.994	-.559	.645	-.253	.315
X17	-.019	-.087	.021	-.077	-.026	-.044	.054	.024	-.177	-.107	.273	.356	-.017	.067	.128	-.110	1.000	-.214	.124	.001	.139	-.077
X18	.265	-.175	-.089	.318	.137	.559	-.082	-.152	.631	.214	-.329	.205	.507	-.050	.166	.994	-.214	1.000	-.562	.634	-.263	.318
X19	-.123	-.006	.006	-.242	-.018	-.474	.180	.157	-.376	-.036	.065	-.231	-.311	-.075	-.105	-.559	.124	-.562	1.000	-.244	.188	-.242
X20	.215	-.241	-.071	.111	.167	.362	.290	-.132	.456	.161	-.251	.270	.369	-.097	.213	.645	.001	.634	-.244	1.000	-.352	.111
X21	-.172	.133	.000	.062	-.026	-.038	-.173	-.072	-.343	-.046	.271	-.040	-.264	.052	.180	-.253	.139	-.263	.188	-.352	1.000	.062
X22	-.024	-.012	.115	1.000	.080	.321	-.299	-.056	.311	-.003	-.177	-.044	.044	.003	.050	.315	-.077	.318	-.242	.111	.062	1.000

Source: Own elaboration from field data (2021).

Note: X1: Age, X2: Education, X3: Farming Experience X4: Total family member X5: Operational Holding (ha) X6: Acreage under Lentil (ha) X7: Land Quality X8: Previous season crop X9: Following season crop X10: Cropping pattern X11: Variety adopted X12: Distance from market X13: Germination percent X14: Seed rate ($kgha^{-1}$) X15: Total operational cost ($Rsha^{-1}$) X16: Production (kg) X17: Quantity consumed (kg) X18: Quantity sold (kg) X19: Transportation expenses (Rs) X20: Middlemen share (Rs) X21: Total expenditure (Rs) X22: Daily intake of pulses per family (g)

Table- A6: Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% Of Variance	Cumulative %	Total	% Of Variance	Cumulative %
1	5.002	22.736	22.736	5.002	22.736	22.736
2	2.380	10.819	33.555	2.380	10.819	33.555
3	1.927	8.759	42.314	1.927	8.759	42.314
4	1.610	7.316	49.630	1.610	7.316	49.630
5	1.271	5.779	55.409	1.271	5.779	55.409
6	1.203	5.470	60.879	1.203	5.470	60.879
7	1.083	4.923	65.802	1.083	4.923	65.802
8	1.072	4.871	70.673	1.072	4.871	70.673
9	.919	4.178	74.851			
10	.829	3.769	78.619			
11	.775	3.524	82.144			
12	.700	3.180	85.323			
13	.627	2.851	88.174			
14	.545	2.479	90.653			
15	.457	2.078	92.731			
16	.431	1.958	94.689			
17	.371	1.688	96.377			
18	.343	1.559	97.936			
19	.249	1.131	99.068			
20	.205	.932	100.000			
21	1.31E-008	5.95E-008	100.000			
22	3.34E-016	1.52E-015	100.000			

Source: Own elaboration from field data (2021).

Extraction Method: Principal Component Analysis.

Table-A7: Component Matrix(a)

	Component							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
AGE	.290	.336	-.189	.320	-.088	.456	.242	.256
EDUCATION	-.206	-.159	.008	.246	-.441	-.233	.444	.335
FARM_EXP	-.064	-.337	.072	-.458	.236	-.030	.103	.201
TOT_FAMILY	.469	-.698	.199	.216	.215	.038	-.206	.271
OH	.233	-.166	.085	-.598	-.054	.113	.057	-.374
ACREAGE_LENTIL	.677	-.139	.213	-.012	-.145	.126	.235	-.244
LQ	-.130	.636	-.109	.088	.402	-.066	-.126	.183
PCROP	-.141	-.156	-.247	-.362	-.084	.551	.354	.243
FCROP	.768	-.096	-.317	-.134	-.017	.065	-.046	-.004
CROPPING_PATTERN	.230	.247	-.188	.421	-.048	-.095	-.059	.011
VARIETY	-.426	.183	.662	-.061	-.220	-.130	-.110	.088
DISTANCE	.198	.408	.637	-.156	-.124	.077	.019	.336
GERMINATION	.545	.258	.082	-.270	-.347	-.149	-.260	-.023
SEED_RATE	-.014	-.028	-.207	.302	-.384	.493	-.458	-.179
TOT_OC	.141	.140	.386	.364	.391	.159	.401	-.317
PROD	.921	.135	.084	.028	-.014	-.036	.049	-.033
QTY_CONSUMED	-.183	.196	.526	-.093	.064	.493	-.228	.103
QTY_SOLD	.924	.112	.027	.038	-.021	-.087	.072	-.043
TRANSPORT	-.618	.028	-.201	-.076	.350	.122	-.074	-.065
MIDDLEMEN	.680	.399	.027	-.104	.336	.015	-.008	.011
TOT_EXP	-.348	-.301	.421	.316	-.046	.073	.099	-.380
DAILY_INTAKE_PULSE	.469	-.698	.199	.216	.215	.038	-.206	.271

Source: Own elaboration from field data (2021).

Extraction Method: Principal Component Analysis (8 components extracted)