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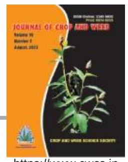

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Technology assessment of pulses and oilseeds in eastern India over last decade

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ABSTRACT

The aim of the current research is to assess and quantify technological change and multiple factors responsible behind pulse and oilseed production in eastern region of India over last decade (2009-10 to 2018-19). Output-oriented DEA-Malmquist technique has been computed for the entire study. The primary driving force behind technological change (TFPCH) in pulses and oilseeds is prenominantly the technical substitution of input utilization (TECHCH)), rather than farmers' efficiency and knowledge (EFFCH) . The state West Bengal dominates in Chickpea (TFPCH quotient 1.127), while Bihar dominates in Lentil (TFPCH quotient 1.306) and Mustard (TFPCH quotient 1.528) cultivation. Orissa features dominancy in Groundnut (TFPCH quotient 1.247) cultivation over the year. Overall TFPCH may be guided by the suitable plant protection measures, proper method of sowing followed by adequate supply of inorganic fertilizer and HYV seeds. Poor quality seed, lack of mechanization with plenty of unskilled labour still prevailed in the eastern states as well. Expansion and utilization of Rice-Fallow areas with paira cropping will raise the overall productivity of these crops in Eastern region of India.

Keywords: DEA-Malmquist, factors, policy strategies, technology

According to the report of FAO 2022, India holds the distinction of being the foremost global producer and consumer of various pulses, accounting for 25% of global production and 27% of global consumption. These pulses are primarily produced and consumed in the country and include crops from the tropics and subtropics like chickpea, black gram, red gram (pigeon pea), green gram (Mungbean), and lentil, which are high in protein, fibre, and vitamins. Unfortunately, the productivity of pulses in India during independence was very poor (441.0 kg ha^{-1} in 1950-51) which is enhanced to 544.0 kg ha^{-1} in 2000-01 and 888.0 kg ha^{-1} in 2020-21 (Devi *et. al*., 2017, DES 2000-01 and 2020-21). Lack of quality seeds with poor germination percent, negligence in cultivation practices as well as ignorance of the farmers became the prime barrier besides the poor productivity of pulses in India decades after decades. In India, the total area planted with pulses is currently 28.8 million hectares (DES 2020-21), a significant increase from twenty six million ha in 2014. (Choudhary and Suri, 2014) and also what it had been during independence (19.1 million ha in 1950-51) with a massive yield gap of on-station and on-farm pulse programmes between other developed countries and also within India.

A significant majority, exceeding three-fourths, of the land dedicated to cultivating pulses in India continues to rely on rainfall for irrigation and cultivated under marginal and sub-marginal land resulting in poor crop productivity in India (Choudhary,, 2013). However, plenty of National and International organizations are working on the enhancement of pulse production and productivity in India with introduction of improved variety breeder seeds, technology demonstrations, frontline demonstrations, policy support and various schemes like National Food Security Mission (NFSM), Rashtriya Krishi Vikas Yojana (RKVY), and accelerated pulses production program (A3P). Government has also launched the International Center for Agricultural Research in the Dry Areas (ICARDA) to advance the production of pulses. By 2050, the nation's need for pulses is expected to reach 39.0 million tonnes, growing at a 2.2% annual rate, in order to attain self-sufficiency. Along with strong legislative backing from the government, this will necessitate a realistic adjustment in research and development strategy. Chickpea (34.55%) has the highest percentage share in total acreage of pulses in India followed by Arhar (16.40%), Urad (14.58%), Moong (14.48%) and Lentil (5.27%) (Average of acreage 2009-10 to 2020-21).

Within the category of field crops, oilseed crops are regarded as the second most significant factor influencing the agricultural economy, after cereals. In

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India, 33.21 million tonnes of oilseeds are produced annually across an area of 27.13 million hectares (quinquennium ending 2019–20), with the bulk of the oilseeds being grown in a rainfed ecosystem (70%). Under the predominant cropping and marketing situations, due to oilseeds' relative lower profitability compared to rival crops like maize, cotton, chickpea etc., the area covered by them has gradually slowed down. Soybean (41.70%) has the highest percentage share in total acreage of oilseeds in India followed by Rapeseed and Mustard (23.54%), Groundnut (19.54%), Sesame (6.63%) and Linseed (1.05%) (Average of acreage 2009-10 to 2020-21).

During 1990s 'Yellow Revolution', there was self-sufficiency in oilseed production which could not be continued beyond a certain period of time. Despite ranking as the fifth largest global producer of oilseeds, India remains one of the prominent importers of vegetable oils due to increasing gap between demand and supply mounting day by day (PEC limited 2016, NMOOP 2018). This scenario has evolved due to static amount of supply with increasing population of the country. The demand for edible oils within the country stands at approximately 25.0 million tonnes, whereas the domestic production is a mere 11.2 million tonnes (The Hindu March 17, 2022). There is a 56.0% discrepancy between supply and demand for edible oils and it is met through imports (Estimated import 13.65 million tonnes in 2022-23 against 13.84 million tonnes in 2021-22) (Dorab Mistry, The Hindu September 23, 2022). Although the domestic oilseeds production of the nine yearly crops demonstrated an admirable Compound Annual Growth Rate of 3.89% in 2018-19, it was unable to keep pace with the rapidly increasing per capita demand, which grew at approximately 6%. This demand surge was attributed to a rise in population and higher per capita income, leading to an enhanced per capita consumption of 22.0 kilograms of oil per person annually (as per NMOOP 2018).

Pulses and oilseeds in eastern India

Bihar and West Bengal are the two major growing states of pulse production in eastern India covering 1.56% and 1.62% acreage respectively (DES 2020-21).These two states are predominated by lentil, pigeon pea, lathyrus (*khesari*), gram, green gram and black gram or maskalai. As time goes on, the agriculture has changed to a cropping system focused on cereals, where pulses are becoming less important. However, the assessment of National Food Security Mission (NFSM) in promoting pulse cultivation in districts under NFSM and non NFSM scheme in 2010 (Chatterjee *et al.*, 2010) was recorded that about 64.0% of the sample farm families cultivate pulses primarily for domestic use. Disease-pest infestation has been cited as a major barrier (28–30%), followed by lower profitability (24%), unstable yields (20%), lack of secured market facilities (16%), lack of irrigation infrastructure and infertile land (14% each), and revenue placed by large farmers only (8%) as the main reasons for abandoning pulse farming. Nevertheless, Bihar will be predicted to be the leading state in eastern India for pulse productivity front (1461.3 kg ha^{-1}) throughout 2050, which in year 2011–12 is 839.3 kg/ha (Singh *et al*., 2013). West Bengal will be projected to follow by.

Eastern India mainly follows rice based cropping system where oilseeds can be easily incorporated to facilitate crop diversification as well as to attain self-sufficiency. Among the states West Bengal and Assam has achieved highest acreage with 3.52% and 1.10% respectively where rapeseed and mustard is considered as the major crop. Introduction of summer sesame under irrigated condition, sunflower and soybean for thermo and photosensitivity (Singh *et al*., 2013), summer Groundnut in water stress areas (Singh *et al*., 2013) and intercropping could raise the overall productivity of oilseeds in the area.

So, there is a basic need to study the impact of technological change on major pulses and oilseeds production throughout eastern India at least for the last decade as well as to suggest suitable policy measures to enhance the production of pulses and oilseeds to assure and judge the overall food and nutritional security of the livelihood across the eastern states of India.

OBJECTIVES

With the view of this above facts, the present study encompasses the technological change in major pulses and oilseeds grown in eastern states of India over the last decade (2009-10 to 2018-19) and also tries to find out those causing factors behind change. To add further, suitable policy and strategy measures have been suggested to enhance the overall pulse and oilseed productivity in our study area.

MATERIALS AND METHODS

Conceptual framework

Two major hypotheses have been established here.

The null hypothesis, H_0, represents that there is no technological change (=1.00) of pulses and oilseeds in eastern India over last decade (2009-10 to 2018-19).

The corresponding alternative hypothesis, H_1, represents that there is technological change of pulses and oilseeds (+1.00 or -1.00) in eastern India over last decade (2009-10 to 2018-19).

The probability of occurrence has been considered as 5% as well as 1% confidence level.

Sampling strategy, stratification and description of the data

Selection of the area for study

To work out the entire study, four major eastern states (Assam, Bihar, Orissa and West Bengal) of India have been chosen purposively.

Selection of the crops for study

Major pulses and oilseeds grown in those states have been purposively considered based on acreage share from 2009-10 to 2020-21.

Selection of data

Secondary data set of productivity and data on various input use of respective pulses and oilseeds across the four states have been considered temporally from 2009-10 to 2018-19.

Selection of major pulses and oilseeds from four major states of eastern India

Regarding computation of technical change by output-oriented DEA-Malmquist method for pulses and oilseeds over last decade in Eastern states of India, only complete sets of data for input and output for the states under pulses and oilseeds have been taken into consideration. These are as follows:

Crops	States
Chickpea	Bihar, West Bengal
Moong	Bihar, Orissa
Arhar	Bihar, Orissa
Urad	Orissa
Lentil	Bihar, West Bengal
Soyabean	NIL
Rapeseeds and Mustard	Assam, Bihar, Orissa, West Bengal
Groundnut	Orissa
Sesame	Orissa, West Bengal
Linseeds	NIL

As the output-oriented DEA-Malmquist indices follow the relative change in input use as well as change in output over two period of time, the ratio does not matter whatever be the unit of the inputs. However, the author has tried to consider the quantity input for seeds (kg.), fertilizer (kg-nutrient), organic manure (quintal), animals used as labour (pair-hours) and humans used as labour (man-hours) but due to unavailability of quantity data for machine labour, total irrigation given and contribution of plant protection measures, the author has included these three parameters as input use in the production function by taking its value terms.

Empirical strategy

To compute the technological change, output-oriented DEA-Malmquist Index of Total Factor Productivity (TFP) (Caves, Christensen and Diewert, 1982) has been used over time (2009-10 to 2018-19) as well as over states. The entire technological (TFP) change has been segregated into technical change (TECHCH) and efficiency change (EFFCH) through DEA-Malmquist methods using DEAP version 2.1 (Coelli, 1996 & 1998), a Data Envelopment Analysis (Computer) Programme.

Data Envelopment Analysis (DEA)

Linear programming is the foundation of this technique that utilizes information regarding amount of inputs and outputs for some states for creating a segmented surface that is linear encompassing points of various data. This frontier is generated through solving a series of linear programming problems, each corresponding to a state in the sample. As a result of the frontier construction process, the extent of inefficiency due to technology, which is indicated by difference within observed data point and the frontier, is established as an additional outcome.

The Output-orientated Malquist productivity Index (MPI) has been used here for measuring change in productivity by using input or output orientated distance functions

Using period s-technology:

$$m_o^s(\mathbf{q}_s, \mathbf{q}_t, \mathbf{x}_s, \mathbf{x}_t) = \frac{d_o^s(\mathbf{q}_t, \mathbf{x}_t)}{d_o^s(\mathbf{q}_s, \mathbf{x}_s)}$$

Using period t-technology :

$$m_o^t(\mathbf{q}_s, \mathbf{q}_t, \mathbf{x}_s, \mathbf{x}_t) = \frac{d_o^t(\mathbf{q}_t, \mathbf{x}_t)}{d_o^t(\mathbf{q}_s, \mathbf{x}_s)}$$

MFP has been calculated by taking geometric mean of both measures at two different technology, s and t.

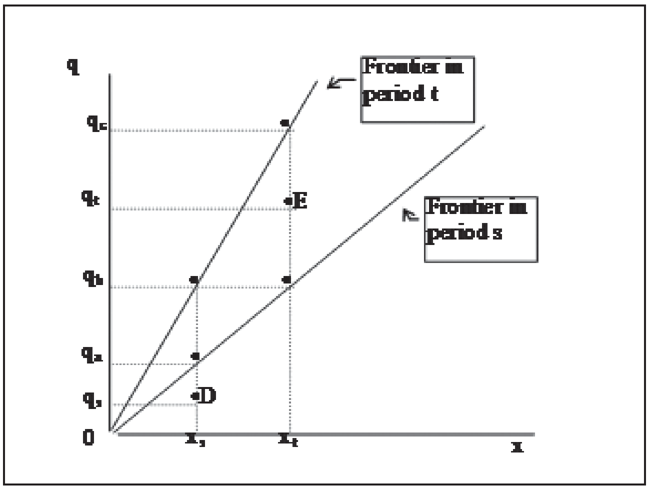
$$m_o(\mathbf{q}_s, \mathbf{q}_t, \mathbf{x}_s, \mathbf{x}_t) = \left[m_o^s(\mathbf{q}_s, \mathbf{q}_t, \mathbf{x}_s, \mathbf{x}_t) \times m_o^t(\mathbf{q}_s, \mathbf{q}_t, \mathbf{x}_s, \mathbf{x}_t)\right]^{0.5}$$

$$= \left[\frac{d_o^s(\mathbf{x}_t, \mathbf{q}_t)}{d_o^s(\mathbf{x}_s, \mathbf{q}_s)} \times \frac{d_o^t(\mathbf{x}_t, \mathbf{q}_t)}{d_o^t(\mathbf{x}_s, \mathbf{q}_s)}\right]^{0.5}$$

It can be decomposed into efficiency change and technical change:

$$m_o(\mathbf{q}_s,\mathbf{q}_t,\mathbf{x}_s,\mathbf{x}_t) = \frac{d_o^t(\mathbf{x}_t,\mathbf{q}_t)}{d_o^s(\mathbf{x}_s,\mathbf{q}_s)}\left[\frac{d_o^s(\mathbf{x}_t,\mathbf{q}_t)}{d_o^t(\mathbf{x}_t,\mathbf{q}_t)} \times \frac{d_o^s(\mathbf{x}_s,\mathbf{q}_s)}{d_o^t(\mathbf{x}_s,\mathbf{q}_s)}\right]^{0.5}$$

Efficiency change	Technical change



Step-wise multiple regressions

To find out the factors contributing and responding most for the change in TFP, multiple correlation and step-wise multiple regression method (SAS version 9.3) between output (Y) and various explanatory factors (X_1…….X_8) has been performed where

$$\mathbf{Y = f(X_{1,}\ X_{2},\ldots .....,\ X_{8})}$$

Y = output, X_1= Seeds (Kg) X_2= Fertilizers (kg of nutrients), X_3= Manures (Quintals), X_4= Humans used as labour (Man hours), X_5= Animals used as labour (Paired hours), X_6= Machine labour (value per Hectare), X_7= Irrigation (value per Hectare), X_8= Pesticide (value per Hectare)

RESULTS AND DISCUSSION

Technological change assessment in major pulses and oilseeds grown in eastern region of India during last decade (2009-10 to 2018-19)

This particular study examines the temporal variation in technology for prominent pulses and oilseeds cultivated in our designated study region from 2009-10 to 2018-19, considering both the year-to-year and state-specific changes. Regarding technological change in pulses across eastern India, mean technology change for Chickpea has been recorded 0.923 ranging from 0.540 in 2011-12 to 1.247 in 2015-16 over the decade, which is slightly less than one and ensures that technology quotient was found to be stagnant and slightly decline as input change dominates the change in output over the year studied. In case of Moong, mean change in technology has been recorded 1.002 ranging between 0.310 in 2011-12 to 2.725 in 2015-16 over the decade ensuring technology quotient was more or less stagnant over the year under study. Mean change in technology for Arhar has been recorded 0.920 where it was lowest in 2017-18 (0.625) and highest in 2016-17 (1.169) over the decade ensuring declining importance of cultivation. The mean technology quotient of Urad has been recorded 0.928 subject to a tremendous range between 0.121 in 2016-17 to 5.197 in 2010-11 over the decade which is slightly less than one too. Mean change in technology for Lentil has been recorded 1.108 over the decade where highest technology quotient was found in 2010-11 (3.357) and lowest in 2014-15 (0.562). The technology quotient for Lentil was found to be slightly gaining as input change dominates the change in output over the year studied (Table 1). The overall table depicts that there was a recess in technology transfer of pulses in 2010-11 and 2011-12 due to failure of NFSM programme which has been gained over the years that

Table 1: Year wise Malmquist EFFCH TECHCH and TFPCH indices for pulses in eastern India (2009-10 to 2018-19)

Crops	YEAR	EFFCH	TECHCH	TFPCH
Chickpea	**2009-10**	1.000	0.682	0.682
	2010-11	1.000	0.669	0.669
	2011-12	1.000	0.54	0.54
	2012-13	1.000	0.911	0.911
	2013-14	0.951	2.429	2.31
	2014-15	1.051	0.404	0.425
	2015-16	1.000	1.247	1.247
	2016-17	1.000	1.06	1.06
	2017-18	1.000	1.674	1.674
	MEAN	**1.000**	**0.923**	**0.923**
Moong	**2009-10**	1.000	1.047	1.047
	2010-11	1.000	2.01	2.01
	2011-12	1.000	0.31	0.31
	2012-13	1.000	1.246	1.246
	2013-14	1.000	1.558	1.558
	2014-15	1.000	0.854	0.854
	2015-16	1.000	2.725	2.725
	2016-17	1.000	0.691	0.691
	2017-18	1.000	0.499	0.499
	MEAN	**1.000**	**1.002**	**1.002**
Arhar	**2009-10**	1.000	0.801	0.801
	2010-11	1.000	0.813	0.813
	2011-12	1.000	0.672	0.672
	2012-13	1.000	0.929	0.929
	2013-14	1.000	1.413	1.413
	2014-15	1.000	0.996	0.996
	2015-16	1.000	1.129	1.129
	2016-17	1.000	1.169	1.169
	2017-18	1.000	0.625	0.625
	MEAN	**1.000**	**0.92**	**0.92**
Urad	**2009-10**	1.000	1.103	1.103
	2010-11	1.000	5.197	5.197
	2011-12	1.000	0.794	0.794
	2012-13	1.000	1.916	1.916
	2013-14	1.000	1.636	1.636
	2014-15	1.000	0.921	0.921
	2015-16	1.000	0.173	0.173
	2016-17	1.000	0.121	0.121
	2017-18	1.000	1.847	1.847
	MEAN	**1.000**	**0.928**	**0.928**
Lentil	**2009-10**	1.000	0.697	0.697
	2010-11	1.000	3.357	3.357
	2011-12	1.000	1.051	1.051
	2012-13	1.000	1.045	1.045
	2013-14	1.000	1.677	1.677
	2014-15	1.000	0.562	0.562
	2015-16	1.000	0.881	0.881
	2016-17	1.000	1.37	1.37
	2017-18	1.000	0.863	0.863
	MEAN	**1.000**	**1.108**	**1.108**

Table 2: State wise summary output of the Malmquist EFFCH TECHCH and TFPCH indices for Pulses in eastern India (2009-10 to 2018-19):

Crops	STATES	EFFCH	TECHCH	TFPCH
Chickpea	Bihar	1.000	0.756	0.756
	West Bengal	1.000	1.127	1.127
	Mean	**1.000**	**0.923**	**0.923**
Moong	Bihar	1.000	0.987	0.987
	Orissa	1.000	1.017	1.017
	Mean	**1.000**	**1.002**	**1.002**
Arhar	Bihar	1.000	1.04	1.04
	Orissa	1.000	0.814	0.814
	Mean	**1.000**	**0.92**	**0.92**
Urad	Orissa	1.000	0.928	0.928
	Mean	**1.000**	**0.928**	**0.928**
Lentil	Bihar	1.000	1.306	1.306
	West Bengal	1.000	0.941	0.941
	Mean	**1.000**	**1.108**	**1.108**

Table 3: Year wise Malmquist EFFCH TECHCH and TFPCH indices for oilseeds in eastern India (2009-10 to 2018-19)

Crops	YEAR	EFFCH	TECHCH	TFPCH
Rapeseed and Mustard	**2009-10**	1.000	1.084	1.084
	2010-11	1.000	1.341	1.341
	2011-12	1.000	1.005	1.005
	2012-13	1.000	1.036	1.036
	2013-14	1.000	1.114	1.114
	2014-15	1.000	1.012	1.012
	2015-16	0.966	1.229	1.188
	2016-17	1.035	1.104	1.143
	2017-18	1.000	1.19	1.19
	MEAN	**1.000**	**1.119**	**1.119**
Groundnut	**2009-10**	1.000	1.06	1.06
	2010-11	1.000	1.359	1.359
	2011-12	1.000	0.76	0.76
	2012-13	1.000	0.978	0.978
	2013-14	1.000	1.369	1.369
	2014-15	1.000	0.745	0.745
	2015-16	1.000	1.1	1.1
	2016-17	1.000	4.071	4.071
	2017-18	1.000	1.486	1.486
	MEAN	**1.000**	**1.247**	**1.247**
Sesame	**2009-10**	1.000	0.46	0.46
	2010-11	1.000	1.509	1.509
	2011-12	1.000	1.315	1.315
	2012-13	1.000	1.029	1.029
	2013-14	1.000	1.265	1.265
	2014-15	1.000	0.873	0.873
	2015-16	1.000	1.03	1.03
	2016-17	1.000	1.09	1.09
	2017-18	1.000	0.836	0.836
	MEAN	**1.000**	**0.997**	**0.997**

Table 4: State wise summary output of the Malmquist EFFCH TECHCH and TFPCH indices for oilseeds in eastern India (2009-10 to 2018-19)

Crops	YEAR	EFFCH	TECHCH	TFPCH
Rapeseed and Mustard	Assam	1.000	0.921	0.921
	Bihar	1.000	1.528	1.528
	Orissa	1.000	0.995	0.995
	West Bengal	1.000	1.12	1.12
	Mean	**1.000**	**1.119**	**1.119**
Groundnut	Orissa	1.000	1.247	1.247
	Mean	**1.000**	**1.247**	**1.247**
Sesame	Orissa	1.000	0.989	0.989
	West Bengal	1.000	1.005	1.005
	Mean	**1.000**	**0.997**	**0.997**

Table 5: Correlation Matrix between change in output over change in various input use of pulses in eastern India during 2009-10 to 2018-19

Crops	States	Dependent variable	Independent variables							
		Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Chickpea	Bihar	1.00	-0.42	-0.71*	-0.37	-0.55	0.65*	0.44	-0.36	-0.37
			(0.23)	(0.02)	(0.29)	(0.10)	(0.04)	(0.21)	(0.30)	(0.30)
	West Bengal	1.00	0.22	0.22		0.22	0.22	0.22	0.61*	0.61*
			(0.55)	(0.55)		(0.55)	(0.55)	(0.55)	(0.05)	(0.05)
Moong	Bihar	1.00	-0.75	0.74	-0.67	-0.67*	-0.71*	0.70*	-0.12	0.54
			(0.01)	(0.02)	(0.04)	(0.03)	(0.02)	(0.02)	(0.72)	(0.10)
	Orissa	1.00	-0.50	0.19	-0.05	-0.70	-0.69	0.64	0.40	0.18
			(0.14)	(0.61)	(0.89)	(0.02)	(0.03)	(0.05)	(0.25)	(0.63)
Arhar	Bihar	1.00	0.14	-0.31	0.58	-0.65	-0.31	-0.45		
			(0.69)	(0.39)	(0.08)	(0.04)	(0.39)	(0.19)		
Urad	Orissa	1.00	0.08	0.73*	0.49	0.05	-0.17	-0.01	-0.13	0.39
			(0.84)	(0.02)	(0.15)	(0.89)	(0.64)	(0.97)	(0.72)	(0.27)
Lentil	Bihar	1.00	-0.27	-0.20	-0.14	-0.64*	-0.14	0.09	-0.53	0.14
			(0.44)	(0.59)	(0.71)	(0.04)	(0.71)	(0.81)	(0.11)	(0.71)
	West Bengal	1.00	0.01	0.05	0.47	0.25	0.15	0.09	-0.02	0.13
			(0.98)	(0.89)	(0.17)	(0.48)	(0.69)	(0.80)	(0.96)	(0.71)

Note: Figures in the parentheses represents respective probability of the coefficients

reflect in technology glut for pulses in 2015-16 and 2016-17 and so on barring Lentil and Urad in eastern India.

While the state-wise analysis of TFPCH for pulses shows that West Bengal witnessed a positive TFPCH for Chickpea (1.127). The quotient is positive for Moong in Orissa (1.017), for Arhar and Lentil it is Bihar (1.040 and 1.306 respectively) (Table-2).

Now coming to the year wise and state wise technological change in oilseeds across eastern India, barring Sesame, Rapeseed and Mustard with Groundnut have witnessed positive change in TFP (1.119 and 1.247 respectively) where the highest change has occurred in 2010-11 for Mustard and 2016-17 for Groundnut (1.341 and 4.071 respectively), ensures a steady change in output over input. Sesame has shown technology quotient slightly less than one (0.997) depicts more or less stagnancy in technology as rate of change of output coincides with input use (Table 3). Regarding state wise evaluation of technology for oilseeds, Bihar, Orissa solely and West Bengal dominates in technology transfer of Mustard (1.528), Groundnut (1.247) and Sesame (1.005) respectively over the last decade (2009-10 to 2018-19) (Table 4). Year wise and state wise EFFCH, TECHCH, TFPCH of Pulses and Oilseeds in Eastern India (2009 to 2018) have been illustrated in Fig. 1-16.

Table 6: Multiple step-wise linear regressions between change in output over change in various inputs use in Pulses across eastern states of India during 2009-10 to 2018-19

Crops	States	Regression equation	Parameters	Remarks
Chickpea	Bihar	Y= 1.46302(-)0.00661X_2^{*} Y= 1.25042 (-) 0.00727X_2^{**}+0.00007274X_6^{*} Y= 1.13158(-)0.00519X_2^{*}+0.00009991X_6^{**} (-)0.00033738X_8^{NS}	X_2: inorganic fertilizer use X_6: machine labour use X_8: plant protection chemicals	Inorganic fertilizer use and Farm mechanization exhibits a significant negative and positive impact upon productivity change of Chickpea as a whole.
	West Bengal	Y= 0.70372+0.00096908X_8^{NS}	X_8:plant protection chemicals	Plant protection measure is the sole contributor over productivity change of chickpea.
Moong	Bihar	Y= 0.77429(-)0.00809X_1^{**}	X_1: seed use	Quality seed material has been identified as the prime factor contributor with a strong significant negative impact on change in productivity of moong.
	Orissa	Y= 0.52547(-)0.00068605X_4^{*}	X_4:human labour use	Human labour use has become the sole contributor with significant negative influence over the overall productivity change in moong.
Arhar	Bihar	Y= 2.12344 (-)0.00172X_4^{*} Y= 2.39056 (-)0.00459X_2^{*}(-)0.00222X_4^{**} Y= 3.99648 (-)0.00510X_2^{**}(-)0.00221X_4^{**} (-)0.08476X_5^{NS}	X_4: human labour use X_2: inorganic fertilizer use X_5: animal labour use	Human labour use becomes the prime contributor followed by inorganic fertilizer use and both have significant negative impact upon productivity change of arhar as a whole.
Urad	Orissa	Y= 0.28161+0.00278X_2^{*}	X_2: inorganic fertilizer use	Inorganic fertilizer use becomes the prime contributor with a significant positive impact over the overall productivity change in urad.
Lentil	Bihar	Y= 1.58883(-)0.00192X_4^{*}Y= 1.55940(-)0.00268X_4^{**}+0.00248X_8^{NS}		X_4:human labour useX_8:plant protection chemicals Human labour use has become the prime contributor with significant negative influence over the overall productivity change in lentil.
	West Bengal	No explanatory variables have reached 15% level of significance for opting output		

NS: Non Significant * Significant at $p_{0.05}$level ** Significant at $p_{0.01}$ level

Table 7: Correlation Matrix between change in output over change in various input use of oilseeds in eastern India during 2009-10 to 2018-19

Crops	States	Dependent variable	Independent variables							
		Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Rapeseed and Mustard	Assam	1.00	0.76*	0.23	-0.43	-0.48	-0.58	0.51	-0.08	0.48
			(0.01)	(0.52)	(0.21)	(0.16)	(0.08)	(0.14)	(0.83)	(0.16)
	Bihar	1.00	0.46	0.44	0.61	0.08	0.11	0.01	0.30	0.61
			(0.19)	(0.20)	(0.06)	(0.83)	(0.77)	(0.99)	(0.41)	(0.06)
	Orissa	1.00	-0.00	0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
			(0.99)	(0.97)	(0.99)	(0.98)	(0.98)	(0.98)	(0.98)	(0.98)
	West Bengal	1.00	-0.26	0.68*	-0.25	-0.49	-0.64*	0.48	0.67*	0.33
			(0.46)	(0.03)	(0.49)	(0.15)	(0.05)	(0.16)	(0.03)	(0.35)
Groundnut	Orissa	1.00	-0.11	0.05	-0.50	-0.42	-0.53	0.40	-0.27	0.36
			(0.77)	(0.89)	(0.14)	(0.23)	(0.12)	(0.25)	(0.46)	(0.31)
Sesame	Orissa	1.00	-0.36	-0.06		-0.55	-0.31	-0.01	-0.17	
			(0.31)	(0.88)		(0.10)	(0.38)	(0.97)	(0.65)	
	West Bengal	1.00	-0.02	0.09	0.08	-0.23	-0.12	0.31	0.14	0.23
			(0.96)	(0.81)	(0.82)	(0.52)	(0.74)	(0.38)	(0.71)	(0.53)

Note: Figures in the parentheses represents respective probability of the coefficient

Factors effecting change in major pulses and oilseeds grown in eastern part of India over the last decade (2009-10 to 2018-19)

Multiple correlation followed by step-wise multiple regression of productivity with all the input use has revealed that the technological change in pulses and oilseeds may be guided by the suitable plant protection measures through introduction of Integrated Pest and Disease Management (IPM and IDM) followed by adequate supply of inorganic fertilizer, quality seed use and farm mechanization. Still poor-quality seed, lack of mechanization with plenty of unskilled labour still prevailed in some traditional pockets of Orissa and Bihar as well.

Regarding cultivation of Chickpea, West Bengal has featured increasing technological change mainly due to overcoming the incidence of Gram pod borer (*Helicoverpa armigera*) by adopting efficient plant protection measures. In case of Moong, Bihar and Orissa both have shown stable productivity mainly due to use of poor quality of seed and employment of unskilled labour respectively. For Arhar, Bihar has featured more or less stagnant technological change by employing unskilled human labour. In spite of application of adequate amount of inorganic fertilizer, other factors being used inefficiently has resulted a stable growth over the years for Urad in eastern India. Bihar has shown stable productivity by employing unskilled human labour and adopting efficient plant protection measures for Lentil (Table 5 and 6).

Regarding oilseeds, Bihar has featured increasing technological change in Rapeseed and Mustard by adopting suitable plant protection measures against Bihar hairy caterpillar (*Spilosoma oblique)* whereas West Bengal and Assam both have achieved more or less stagnant technological change mainly due to adequate application of fertilizer and use of good quality of seeds respectively. In case of Groundnut, Orissa has exhibited more or less stagnant technological change due to lack of mechanization, dominancy of animal labour and use of poor quality of seeds. In case of Sesame, the stable technological change of Orissa is due to unskilled human labour use. (Table 7 and 8).

Discussion and Policy measures

The current study aims to assess the technological change in major pulses and oilseeds grown in Eastern states of India over the decade and find out the factors responsible for the change. DEA-Malmquist productivity indices for all major pulses and oilseeds grown in eastern states of India were computed subsequently over a decade (2009-10 to 2018-19) as per availability of complete secondary data set. The results show a striking feature that technological changes of all major pulses and oilseeds in eastern India are mainly driven by the technical replacement between quality factor use but not by change in growers' efficiency. To attain enhanced productivity, it is crucial to elevate efficiency levels while simultaneously ensuring equitable adoption of new technologies (Chaudhary, 2012). Pulse is an essential food items in

Table 8: Multiple step-wise linear regressions between change in output over change in various inputs use in Oilseeds across eastern states of India during 2009-10 to 2018-19

Crops	States	Regression equation	Parameters	Remarks
Rapeseed and Mustard	Assam	$Y= 0.01674+0.05582X_1^{**}$	X_1: seed use	Quality seed material has been identified as the prime factor contributor with a strong significant positive impact on change in productivity of rapeseed and mustard.
	Bihar	$Y= 1.13157 +0.00049916X_8^{NS}$	X_8:plant protection chemicals	Plant protection measure is the sole contributor over productivity change of rapeseed and mustard.
	Orissa	No explanatory variables have reached 15% level of significance for opting output		
	West Bengal	$Y= 0.91145+0.00117X_2^{*}$	X_2:inorganic fertilizer use	Inorganic fertilizer use becomes the prime contributor with a significant positive impact over the overall productivity change in rapeseed and mustard.
Groundnut	Orissa	$Y= 1.37994(-)0.00160X_5^{NS}$ $Y= 2.93308 (-)0.01074X_1^{NS}$ $(-)0.00253X_5^{*}$	X_5:animal labour use X_1: seed use	Animal labour use becomes the prime contributor with significant negative impact upon productivity change of groundnut as a whole.
Sesame	Orissa	$Y= 0.26196$ contributor $(-)0.00010284X_4^{NS}$ $Y= 0.29642+ 0.00294X_2^{*}(-)0.00022583X_4^{**}$	X4:humanlabour use X_2:inorganic fertilizer use	Human labour use has become the prime with negative influence upon the productivity change in sesame followed by inorganic fertilizer use with a significant positive influence over the overall productivity change in sesame.
	West Bengal	No explanatory variables has reached 15% level of significance for opting output		

NS: Non Significant * Significant at $p_{0.05}$ level** Significant at $p_{0.01}$ level

Year wise and state wise EFFCH, TECHCH, TFPCH of Pulses and Oilseeds in Eastern India (2009-2018)

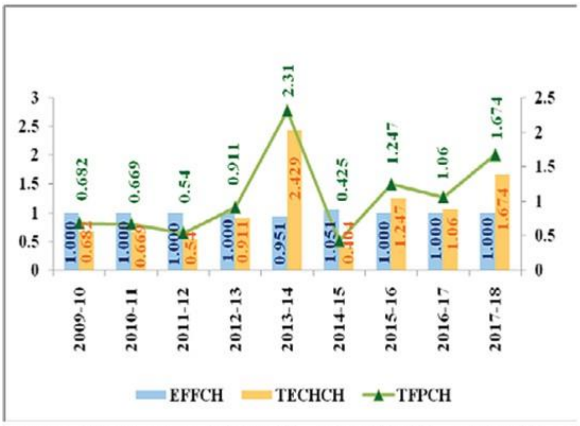


Fig.1: **Year-wise EFFCH, TECHCH, TFPCH of Chickpea in Eastern India (2009-10 to 2018-19)**

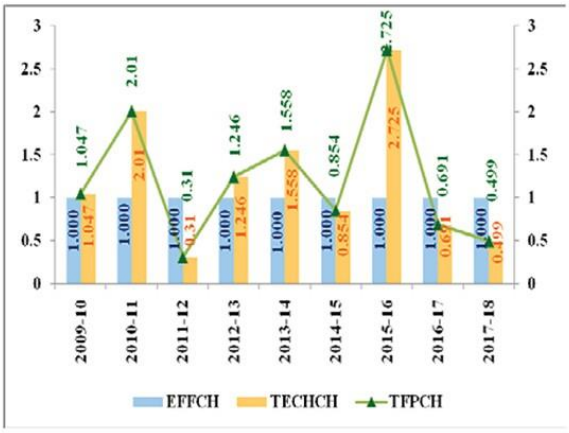


Fig.2: **Year-wise EFFCH, TECHCH, TFPCH of Moong in Eastern India (2009-10 to 2018-19)**

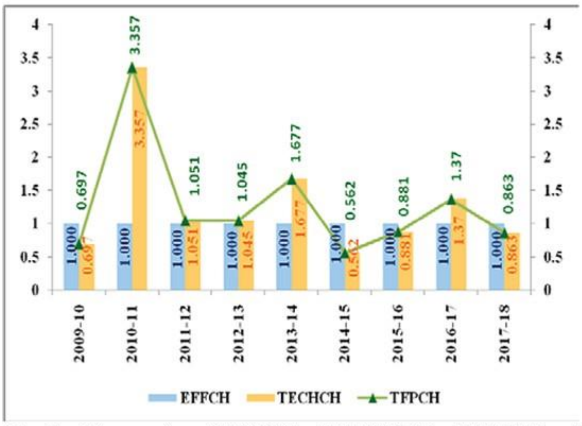


Fig.3: **Year-wise EFFCH, TECHCH, TFPCH of Lentil in Eastern India (2009-10 to 2018-19)**

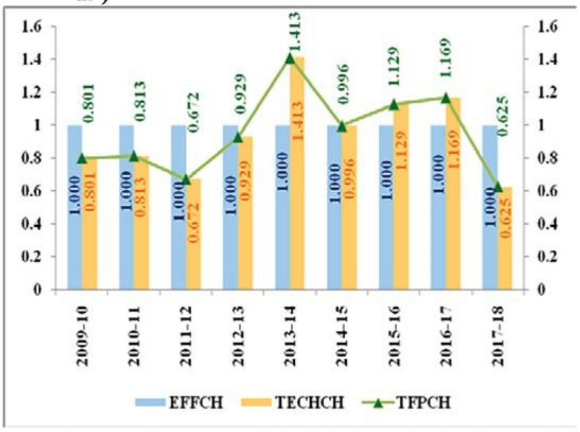


Fig.4: **Year-wise EFFCH, TECHCH, TFPCH of Arhar in Eastern India (2009-10 to 2018-19)**

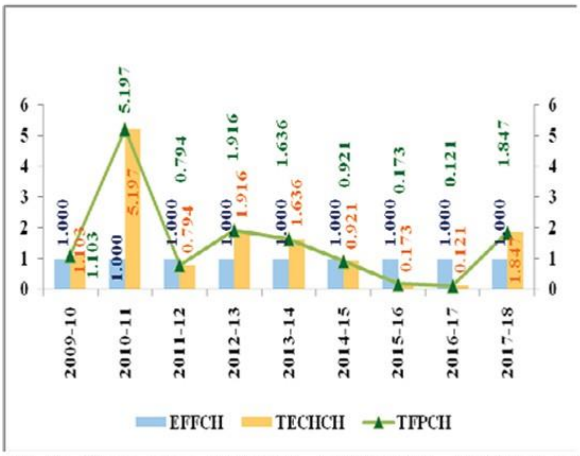


Fig.5: **Year-wise EFFCH, TECHCH, TFPCH of Urad in Eastern India (2009-10 to 2018-19)**

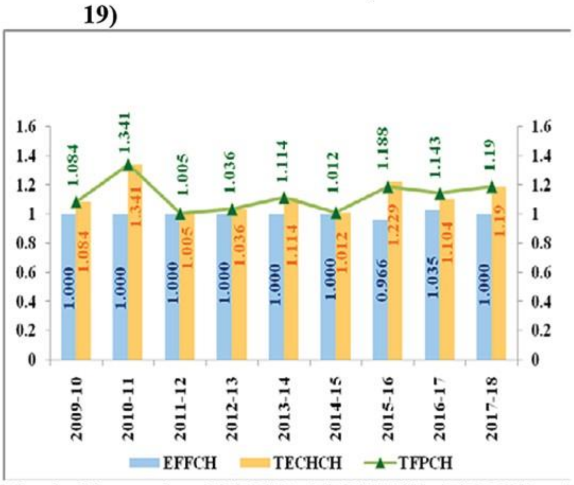


Fig.6: **Year-wise EFFCH, TECHCH, TFPCH of Rapeseed and Mustard in Eastern India (2009-10 to 2018-19)**

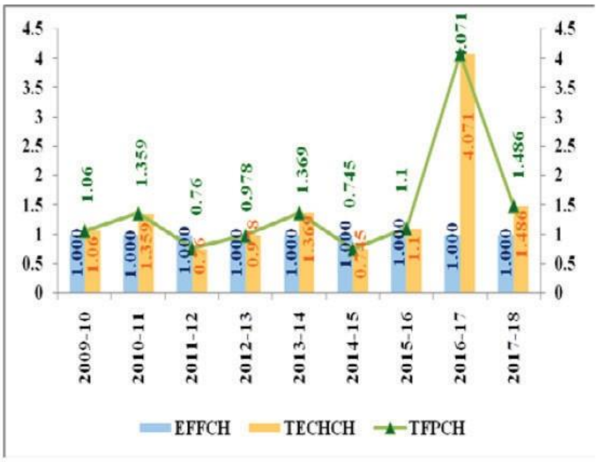


Fig.7: **Year-wise EFFCH, TECHCH, TFPCH of Groundnut in Eastern India (2009-10 to 2018-19)**

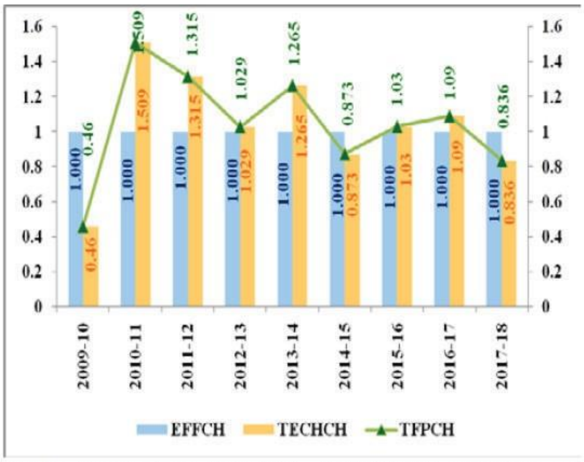


Fig.8: **Year-wise EFFCH, TECHCH, TFPCH of Sesame in Eastern India (2009-10 to 2018-19)**

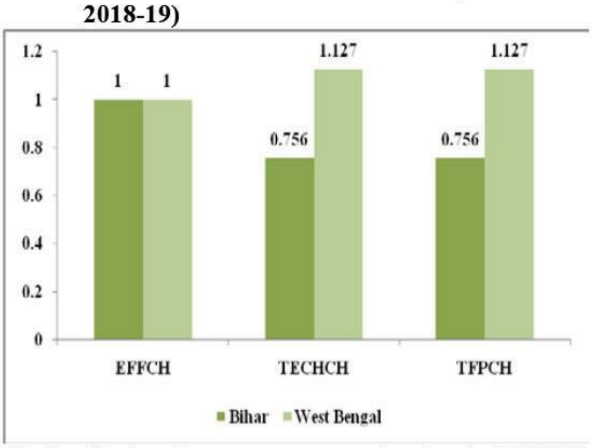


Fig.9: **State-wise summary output of EFFCH, TECHCH and TFPCH of Chickpea in Eastern India (2009-10 to 2018-19)**

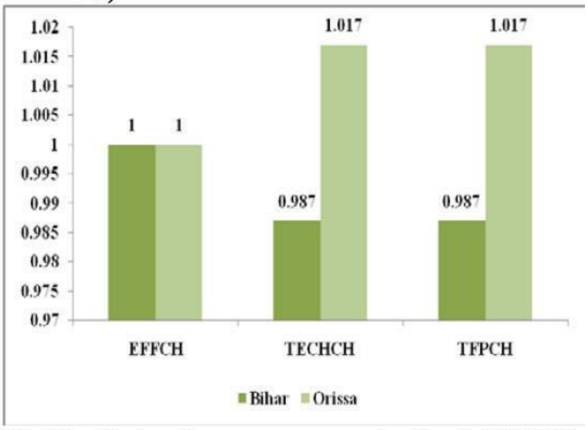


Fig.10: **State-wise summary output of EFFCH, TECHCH and TFPCH of Moong in Eastern India (2009-10 to 2018-19)**

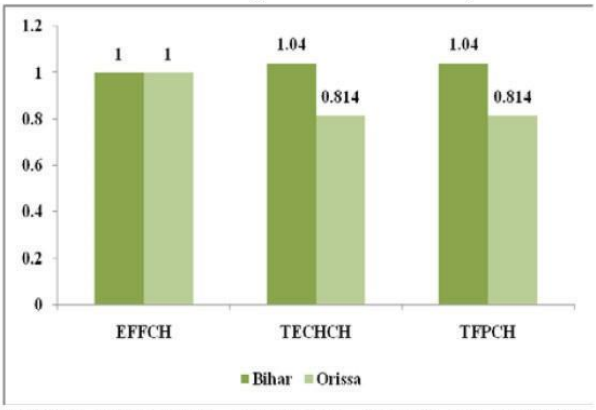


Fig.11: **State-wise summary output of EFFCH, TECHCH and TFPCH of Arhar in Eastern India (2009-10 to 2018-19)**

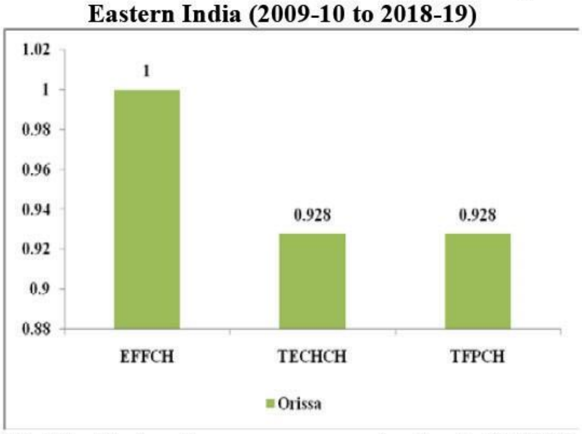


Fig.12: **State-wise summary output of EFFCH, TECHCH and TFPCH of Urad in Eastern India (2009-10 to 2018-19)**

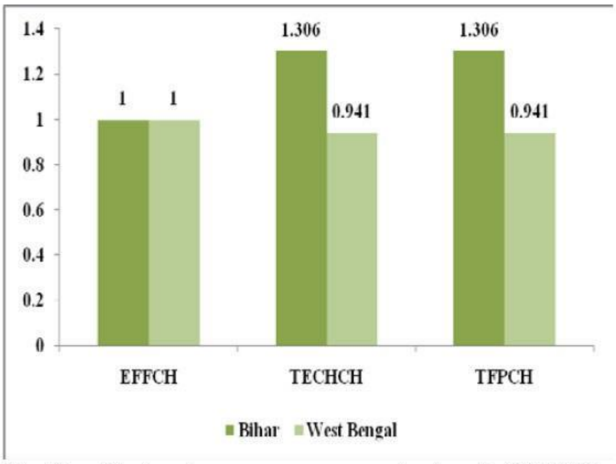


Fig.13: State-wise summary output of EFFCH, TECHCH and TFPCH of Lentil in Eastern India (2009-10 to 2018-19)

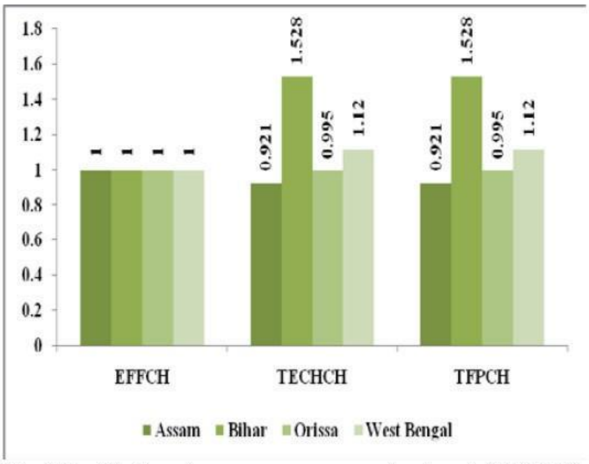


Fig.14: State-wise summary output of EFFCH, TECHCH and TFPCH of Rapeseed and Mustard in Eastern India (2009-10 to 2018-19)

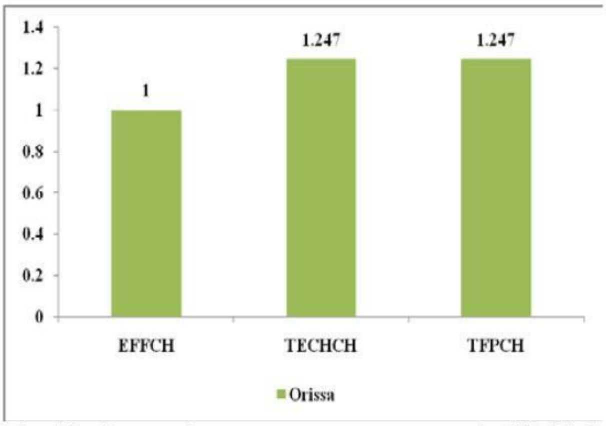


Fig.15: State-wise summary output of EFFCH, TECHCH and TFPCH of Groundnut in Eastern India (2009-10 to 2018-19)

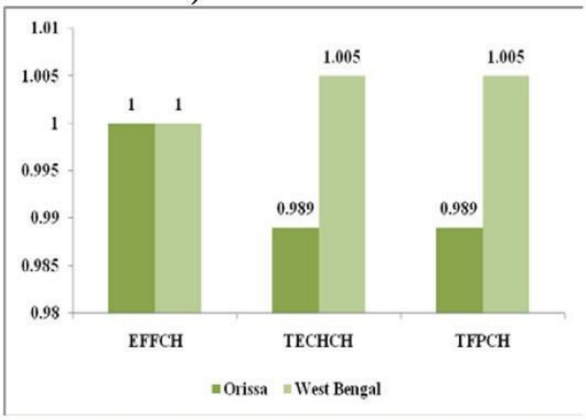


Fig.16: State-wise summary output of EFFCH, TECHCH and TFPCH of Sesame in Eastern India (2009-10 to 2018-19)

our daily life and a rich source of protein, fibre and vitamins. In order to meet the per capita per day requirement of 40 g of pulses, attention has to be paid for production and consumption in India. The development of accessible technologies appropriate for new cropping patterns and marginal areas will assist to increase pulse production in India, perhaps addressing protein underconsumption (Suresh *et al*., 2016). Regarding oilseeds production, technological change became decelerated after 2000 because of overuse of chemical fertilizer and insecticides/pesticides while Rapeseed and Mustard and Groundnut have shown significantly positive impact to overall change in technology of oilseeds in eastern states of India as indicated by Kurup *et al*., 2015.

Region specific policy and strategy measures have should be done in order to increase eastern India's total production of pulses and oilseeds. By creating chickpea varieties that are non-lodging, sensitive to high input circumstances, early to extra-early mature, and adaptable to reproductive stage heat tolerance, the chickpea crop may be made more lucrative and competitive. JG 14 (ICCV 92944) is an early maturing, heat-tolerant chickpea cultivar that is already gaining popularity in Eastern India. For Arhar, ICRISAT has already started a breeding strategy to create early maturing lines that are photo- and thermo-insensitive as well as a non-determinate group (ICPL 20325, ICPL 20326, and ICPL 11301). Regarding Lentil, an early maturing variety (L-4717) for Rice-Fallow areas with sufficiently good pod yield should be recommended in *rabi* season. Following methodical technology transfer, several front-line demonstration results have amply demonstrated the potential for increasing pulse yields in farmers' fields, particularly in the spring/summer season. Introduction of biotic stress tolerance and transgenic varieties for disease/pest tolerance in Chickpea susceptible to Dry root rot and Fusarium wilt and Pod Borer would be suggested. Lastly, it is imperative to consider current market prices rather than relying solely on the minimum support price (MSP) for pulse crops. This adjustment will help address the supply-demand disparity and make the MSP more effective, as recommended by Reddy in 2009.

The potential for growing pulse crops in rice-fallows, which are typically not watered, has to be taken advantage of. In MP (78% of the *kharif* rice acreage, or 4.4 million ha), Bihar (2.2 million ha), and West Bengal (1.7 million ha), there are large areas of fallow land that are best suited for the cultivation of pulses. Dr. Alagh's task team on pulses identified the regions that may see growth (Reddy, 2015):

- Examining the 3 to 4 million hectares of fallow rice land, mostly in Eastern India, which can produce abou 2.5 million tonnes, to identify more area.
- About 5 lakh hectares of upland rice, 4.5 lakh hectares of millets, and 3 lakh hectares of barley, mustard, and wheat, all of which are now producing poorly, might be diversified into kharif/rabi pulses.
- In UP, Punjab, Haryana, Bihar, Gujarat, and West Bengal where adequate irrigation facilities exist and the menace of blue bull is contained, pigeon pea on rice bunds and intercropping in particular agroclimatic regimes is identified, approximately 16.5 lakh ha area vacated by wheat, peas, potato, and sugarcane can be used for raising 60–65 day summer mungbean crop (Singh *et. al.* 2016).

There are necessary institutional support strategies or inventions for enhancing the productivity of annual oilseeds and oil palm in the country that are time tested with scale neutrality and can be grounded for enhancing productivity, categorized under the situations listed below:

- Improvement in the amount of seed production distribution of new varieties
- High impact technologies with minimum cost involvement for income enhancement
- Emphasis on eco-friendly and high input use efficiency of technologies with high return on investment (ROI)
- Focus on skill development through entrepreneurship development with special attention to quality improvement as well as value addition.

Region based suggestion of bringing additional areas under pulses

Serial No.	Potential crops/Cropping systems	Specific Area
	Intercropping	
1.	Sugarcane with mungbean throughout the months of spring and summer (irrigated) (Rainfed Uplands)	Bihar
	Mungbean with cotton and millets	
	Intercropping chickpea with barley, mustard, linseed, and safflower in a rainfed environment	Bihar
	Chickpea or lentils with sugarcane grown in the autumn	Bihar
2.	Mungbean: the only crop grown in the months of spring and summer.	Bihar, West Bengal
3.	**Rice-fallow areas**	
	Chickpea	Eastern Uttar Pradesh, Bihar, Jharkhand, Orissa, West Bengal
	Urdbean/Mungbean	Orissa
	Lentil as *paira cropping*:Promising suggested varieties: 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)	Eastern U.P., Bihar, West Bengal, Assam, Jharkhand
	Lentil/fieldpea	North-East
4.	Lentil in Diara lands	Bihar
5.	Pigeon pea on the foothills of the sloping terrain	North Bihar

CONCLUSION

The current investigation has reached a few distinct results, which are:

- Rapeseed Mustard is the major oilseeds grown in eastern belt and also the emergence of Sesame cultivation has been observed
- The growth of Total Factor Productivity Change (TFPCH) in pulses and oilseeds remains relatively stagnant, primarily driven by the technical substitution of input use rather than efficiency improvements. The efficiency change component (EFFCH) was observed to show minimal progress across all the chosen crops
- Technological advancement in Chickpea has been occurred in West Bengal (TFPCH quotient 1.127) while Bihar has grabbed a significant higher change in technology for Lentil (TFPCH quotient 1.306) over the year. Bihar too has occupied the highest significant positive change in technology for Rapeseed Mustard over the year studied (TFPCH quotient 1.528) and also Groundnut has shown significant positivity in technological advancement for the state Orissa (TFPCH quotient 1.247)
- The technological change is mainly guided by technical substitution of quality input use, plant protection measures followed by inorganic fertilizer
- Poor quality seed, lack of mechanization with plenty of unskilled labour still prevailed in the state of Orissa and Bihar as well
- Introduction of HYV, proper land preparation, *paira* cropping in Rice-Fallow situation will raise the overall productivity of pulses and oilseeds in the study area.

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