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Impact of *Kharif* Pulses in North East India: Yield Gap and Economic Analysis

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ABSTRACT

Background: The study was carried out to assess the performance of cluster frontline demonstrations (CFLDs) in terms of yield gap and economic analysis of black gram (var. PU-31, SBC-40, IPU- 02-43, SKPD-3) and green gram (Pratap, SGC-20, SGC-16, Samrat) in three states of North East *i.e*. Arunachal Pradesh, Assam and Sikkim during 2016-2021 in *kharif* season.

Methods: Krishi Vigyan Kendras of these three states conducted 4038, 2011 demonstrations covering 1460 ha, 630 ha area in black gram and green gram, respectively during 2016-2021 through improved production technology. Out of the total 6049 farmers randomly 2350 farmers were selected for testing their knowledge level and extent of adoption of improved practices by means of a well-structured scheduled.

Result: The findings unveiled that in all the three states, average grain yield in demonstration fields were higher than farmer's practice. Black gram recorded highest demonstration yield (9.83 q/ha) in Sikkim followed by green gram (8.87 q/ha) in Arunachal Pradesh as compared to farmers' practices (6.64 q/ha) and (5.64 q/ha), respectively. However, Sikkim recorded highest net return of Rs. 86,644/ha in green gram and Rs. 32,328/ha in black gram. It was also observed that majority of farmers from Sikkim adopted most of the improved technologies with 62.33% followed by Assam (53.55%) and Arunachal Pradesh (50.00%) which is highly encouraging.

Key words: Black gram, Cluster frontline demonstrations, Green gram, Pulses, Yield gap.

INTRODUCTION

Indian population is predominantly vegetarian and the source of dietary protein requirement for the growth and development of human beings is mostly met with pulses. Pulses are known as "Poor man's meat" and "rich man's vegetable" as they contain protein, minerals and vitamins. The protein content of pulses is three times higher than cereals (Grover and Singh, 2015). Apart from the human diet, pulses, being leguminous, have an important and unique property of maintaining and restoring soil fertility through biological nitrogen fixation as well as conserving physical properties of soil by virtue of their deep root system. Pulses are vital for enhancing soil quality and fertility due to their ability to fix biological nitrogen, deep root systems and capacity to absorb insoluble soil elements (Yadav *et al.,* 2024). Due to its deep roots, pulses are incredibly adaptable to the country's dry land areas, which make up a significant amount of the cropped area and greatly contribute to the total production of pulses. Pulse also forms an important fraction of cattle feed and fodder as hay, green fodder and concentrates, *etc*. India is the large producer, importer and consumer of pulses. Pulses contribute protein for a majority of the Indian population. Pulses contribute 11% of the entire intake of proteins in India (Reddy, 2010). India is the largest producer in the world, with 26 per cent share in the global production by producing 25.23 million tonnes of pulses from an area of 29.99 million hectares, still India is leading importer and about 20 per cent of the total pulses demands are met by imports only due to the stagnant production over the years (Divya *et al.,* 2024) The North East Region (NER) of India is made up of 8 states, namely Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Tripura and Sikkim covering about 8.3% geographical area with approximately 4% populations of the country. In NER of India, around 77% of the land is hilly area and senile plateau, while the cultivated area is only 12%. The agrarian community here farms on subsistence level. The major pulses grown in the region are blackgram, green gram, pigeon pea, rice bean, cowpea *etc*. in *kharif* and French bean, chickpea, lentil, lathyrus and field pea in *rabi* season. In hills, various other beans such as faba bean or broad bean, adzuki bean, moth bean and lablab bean are also grown as pulse. The North-Eastern Region of India possesses soil and agro-climatic conditions suitable for pulses cultivation. Despite this favourable

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environment, the region struggles with an 82% shortfall in meeting its pulses requirements. However, the average yield of pulses in the NER is notably higher at 848 kg/ha, surpassing the national average of 764 kg/ha indicating that that Northeast India has a huge potential in pulse production (Singha *et al,* 2020). Therefore, it is recommended that the extension agencies engaged in application of agricultural technologies on farmer's field should give priority to organize frontline demonstrations on cluster basis for harnessing the productivity potential of pulse crops, reduce the technology gap, technology adoption and minimizing the disease and insect infestation.

Cluster front line demonstrations (CFLDs) represent a fresh approach aimed at facilitating direct engagement between researchers and farmers to accomplish the exchange of technologies and gather firsthand feedback from the agricultural community. The National Food Security Mission (NFSM), a centrally sponsored Scheme established to fulfil the objectives outlined in the National Development Council (NDC) resolution, focuses on boosting the production of rice, wheat and pulses (Anonymous, 2011). Within this mission framework, the concept of Cluster front line demonstrations operates on a mission-oriented basis, prioritizing the needs of farmers. The scheme's primary goal is to target specific regions by providing improved technologies such as Integrated Nutrient Management (INM), Integrated Pest Management (IPM), promotion of micronutrients/bio-fertilizersand sprinkler irrigation. Additionally, it includes provisions for extension services, training and mass media campaigns. These demonstrations are overseen by scientists from Krishi Vigyan Kendras, State Agricultural Universities (SAUs) and their Regional Research Stations. In the year 2019-20, pulse cultivation covered an area of 27.99 lakh hectares, with Northeast India contributing 2.673 lakh hectares. Notably, the average productivity of pulses in India during the same period was 822.7 kg/ha, while in Northeast India, it stood higher at 1049.157 kg/ha, surpassing the national average. This observation underscores the significant potential for pulse production in Northeast India.

The aim of this investigation was to evaluate how CFLD practices impact the productivity of kharif Pulses such as black gram and green gram, focusing on factors like grain yield, extension gaps, technological gap, economic analysis, farmers' knowledge levels and adoption rates in Assam, Arunachal Pradesh and Sikkim.

MATERIALS AND METHODS

The present study was carried out by the KVKs of Assam, Arunachal Pradesh and Sikkim in *Kharif* seasons at the farmers' fields during the period from 2016-17 to 2020-21. To assess the yield gap and economic analysis, a total number of 4038, 2011 demonstrations covering 1460 ha, 630 ha area in black gram and green gram, respectively during 2016-2021. Out of the total 6049 farmers randomly 2350 farmers were selected for testing their knowledge level and extent of adoption of improved practices by means of a well-structured scheduled. The KVKs implemented all technological interventions in accordance with the practice packages for various pulse crops (Table 1). The awareness programmes for the farmers were organized by the Scientists of KVKs as part of technological interventions with improved package of practices in demonstration plots at farmers' fields. The farmer practice was considered as control plot/farmers practice which was maintained by the farmers by traditional cultivation practices with mix varieties. For demonstration plots, the farmers received essential resources from the KVKs, including high-quality seeds, fertilizers, integrated pest management (IPM), tools and biofertilizers, along with expert support. The procedures recommended by Choudhary (1999) were followed for the selection of the demonstration site, farmers and other related activities. The KVKs Scientists used to visit the demonstrations fields and farmer's practice (control) on regular basis for close supervision and data collection during the entire process of demonstration programmes.

$$\% \text{ Yield increase over farmers practice} = \text{Demonstration plot yield} - \text{Farmers plot yield}$$

Extension of technology gap, extension gap technology index

The estimation of technology gap, extension gap technology index was done using following formula (Kadian *et al*., 1997; Samui *et al*., 2000).

i) Texgnology gap= Potential yield - Demonstration plot yield

ii) Extension gap = Demonstration plot yield - Farmers plot yield

iii) $$\text{Technology index (\%)} = \frac{Pi - Di}{P1} \times 100$$

Where,

P_i = Potential yield of crop.

D_i = Demonstration plot yield of crop.

Economic analysis

The expenses involved in cultivating pulses encompass input costs such as seed expenditures, fertilizers, pesticides purchased by the farmers in farmers' practice / supplied by the Krishi Vigyan Kendras as well as hired man power (if any), sowing charges of bullocks / tractor, post-harvest operation charges. The gross net-returns were calculated considering the cost of cultivation of grain yield. Similarly, the Benefit-Cost-Ratio (BCR) was calculated as a ratio of net-returns corresponding costs of cultivation as followed by Vedna *et al*. (2007); Ojaha and Bisht (2020); Singha *et al*. (2020) and Singh *et al*. (2020).

Knowledge level, extent of adoption of improved technologies and constrains: The enquiry was conducted randomly on Assam (1500 farmers), Arunachal Pradesh (500 farmers) and Sikkim (350 farmers) were selected out of the total 2350 farmers for testing their level of knowledge

extent of adoption of improved technologies and constrains about pulse crops by means of a well-structured scheduled.

RESULTS AND DISCUSSION

Grain yield

Throughout the study, it was found that, in comparison to the respective farmer's practices in Assam, Arunachal Pradesh and Sikkim, cluster front-line demonstrations of improved technology increased productivity. Data presented in Table 2 revealed that as a result of knowledge and transfer of improved farm technology under cluster frontline demonstrations, the grain production under demonstration plot was increased by 15.58 to 57.26 per cent. In the demonstrated plots, an average yield of 8.37 q/ha was reported, while farmers' practices produced 6.06 q/ha. The state of Sikkim had the highest average yield of CFLD plots for black gram, 9.83 q/ha, compared to farmers' practice (6.64 q/ha) with 38.87 per cent increase in yield followed by green gram (Arunachal Pradesh) 8.87 q/ha and green gram (Sikkim) 8.38 q/ha compared to farmers' practice. The findings clearly reveal that the demonstration plots had greater average yield over the years compared to farmers' practice due to knowledge and adoption of package of practices such as use of high yielding varieties, integrated nutrients management and integrated pest management. The above findings were in agreement with Surywanshi and Prakash (1993); Hiremath and Nagaraja (2007); Mishra *et al*. (2009); Tomar (2010); Singh *et al.* (2014); Dhaka *et al.* (2015); Kumar *et al*. (2017); Singha *et al*. (2020); Ojaha *et al*. (2020) and Gogoi *et al.* (2022).

Extension gap

The term "extension gap" refers to the differences between the yields of farmers' practices and demonstration plots. In five consecutive years, demonstrated technology and farmers practices in Assam, Arunachal Pradesh and Sikkim were found to have an extension gap ranging from 1.13 to 3.23 quintal per hectare for black and green grams, with an average of 2.31 quintal per hectare. The extension gap was recorded lowest in green gram in the state Sikkim (1.13 q/ha) and highest was recorded in green gram in the state Arunachal Pradesh *i.e*. 3.23 q/ha (Table 2). The adoption of better technology in the demonstration plot, which resulted in a higher grain production than the traditional farmers' practices, may be the cause of the

Table 1: Details of recommended package of practices for CFLD Pulses in North East region.

Technological intervention	Recommended packages of Practice followed in CFLDs			
	Black gram (*Vigna mungo)*		Green gram (*Vigna radiata*)	
	Demonstration plot	Farmers practice	Demonstration plot	Farmers practice
Variety	PU-31, SBC-40, IPU- 02-43, SKPD-3	Local	Pratap, SGC-20, SGC-16, Samrat	Local
Method of sowing	Line sowing	Broadcasting	Line sowing	Broadcasting
Time of sowing	Mid-August to mid-September	September till first week of October	Mid-August to mid-September	September till first week of October
Seed rate	NPK 15:35:0 kg/ha/ vermicompost @ 30 kg/ha	FYM lower NPK dose	NPK 15:35:0 kg/ha/ vermicompost @ 30 kg/ha	FYM lower NPK dose
Seed treatment	Rhizobium/inoculation @ 5 g kg seed and PSB inoculation @ 3 kg/ha	Nil	Rhizobium inoculation @ 5 g/kg seed and PSB inoculation @ 3 kg/ha, Trichoderma spp. @ 5 g/kg of seed	Nil
Fertilizer management	FYM/compost 10 t/ha, urea @ 22 kg/ha, SSP @ 220 kg/ ha, MOP @ 25 kg/ha	Nil	Integrated nutrient management vermicompost @ 1 t/ha, urea @ 22 kg/ ha, SSP @ 220 kg/ha, MOP @ 25 kg/ha, lime @ 65.5 kg/ha as soil amendment	Nil
Disease management	One weeding at 20-25 days after sowing (DAS)	No weeding	Pendimethalin @ 1.0 kg/ha as pre-emergence, one weeding at 20-25 (DAS)	Nil

variation. High-yielding cultivars combined with an increasing amount of modern production methods will transform and fill the extension gap. This finding is in corroboration with the findings of Hiremath and Nagaraju, (2010); Raju *et al*., 2017; Ojaha and Bisht (2020); Singha *et al*. (2020); Singh *et al*. (2020) and Gogoi *et al*. (2022).

Technology gap

Wide technology gap was observed in three different states and it was lowest in green gram, Arunachal Pradesh (1.13 q/ha) and highest was recorded in black gram in the state Assam (4.77 q/ha). On five consecutive years, average technology gap of total 6049 demonstrations were found as 2.63 quintal per hectare (Table 2). The possible reason for the difference in the technological gap could be the higher feasibility of recommended technologies in various north eastern states. The difference in technology gap might be due to more feasibility of recommended technologies in different states of north east region. The observed technology gap may be caused by differences in soil fertility, rainfall distribution, infestation of diseases and pests and geographical changes. Raj *et al*. (2013) also reported on the technological yield gap in crops caused by variations in soil fertility and weather. Similar results were also reported by Balail *et al.,* (2013); Mukherjee., (2003*);* Kumar *et al*., (2017*);* Ojaha *et al.,* (2020)*;* Singha *et al.,* (2020); Singh *et al.,* (2020) and Gogoi *et al.,* (2022).

Technology index (%)

For five years in a row, the technology index for every *kharif* pulse demonstration held in Assam, Arunachal Pradesh and Sikkim complied with the technology gap. The technology index varied from 11.33 to 39.74 per cent (Table 2). The highest technology index per cent of 39.74 was recorded in black gram in the state Assam followed by black gram in Arunachal Pradesh (24.50 per cent) and lowest was observed in green gram in the state Arunachal Pradesh which is 11.33 per cent. The technology index indicates whether advanced technology can be implemented in farmer's fields; the lower the index's value, the more feasible advanced technology is (Table 2). During the CFLD program, an average technology index of 23.60% was recorded, indicating the effectiveness of well-executed technological interventions. This will promote the adoption of technical interventions in Northeast region that have been shown to improve *kharif* pulse yield performance. Similar findings were also reported by Jeengar *et al.* (2006); Kumar *et al.* (2017); Ojaha and Bisht (2020); Singha *et al.* (2020) and Singh *et al.* (2020).

Economic analysis

The economics of *kharif* pulse crops production under cluster frontline demonstration in Assam, Arunachal Pradesh and Sikkim were estimated and the results have been shown in Table 3. According to an economic analysis conducted between 2016 and 2021, *kharif* pulses,

Table 2: Productivity, extension and technology gap and technology index of CFLD on pulses from 2016-17 to 2020-21 (average over years).

State	Pulse	Demo (No)	Area (ha)	Potential yield	Farmers practice (q/ha)	Demo yield (q/ha)	% increase over Farmers practice	Extn. Gap q/ha	Tech gap q/ha	Tech. index (%)
Assam	Blackgram	2945	1090	12	5.56	7.23	30.27	1.67	4.77	39.74
	Greengram	1572	480	10	5.60	7.59	35.59	1.99	2.41	24.15
Arunachal Pradesh	Blackgram	755	240	11	5.67	8.31	46.48	2.64	2.69	24.50
	Greengram	150	40	10	5.64	8.87	57.26	3.23	1.13	11.33
Sikkim	Blackgram	338	130	12	6.64	9.83	48.04	3.19	2.17	18.06
	Greengram	289	110	11	7.25	8.38	15.58	1.13	2.62	23.82
	Total/avg.	6049	2090	-	6.06	8.37	38.87	2.31	2.63	23.60

Table 3: Average annual cost of the cluster front-line pulses demonstrations at farmers' fields from 2016-17 and 2020-21.

State	Pulse	Gross cost (Rs./ha)		Gross returns (Rs./ha)		Net return (Rs./ha)		B:C ratio	
		CFLD	Farmers practice	CFLD	Farmers practice	CFLD	Farmers practice	CFLD	Farmers practice
Assam	Blackgram	19634	18113	44302	33634	24668	16429	2.33	2.00
	Greengram	24313	21533	54178	36367	29865	14833	2.2	1.68
Arunachal Pradesh	Blackgram	22450	19250	54350	32700	31900	13450	2.42	1.69
	Greengram	21750	19650	46920	33000	25170	13350	2.14	1.67
Sikkim	Blackgram	35083	29296	73411	53760	38328	24463	2.09	1.84
	Greengram	45313	47244	137831	121038	86644	73794	3.04	2.56
	Total/Average	28090	25848	68499	51750	39429	26053	2.37	1.91

specifically black and green gram, under cluster front line demonstrations had higher gross returns. The cost of implementing new technologies in pulse crops varies and can be more profitable. The main causes of the high cost of cultivation in demonstration fields compared to farmers practice are the use of high yielding seeds, seed treatment, chemical fertilizer application, pest management and other input and output prices of the commodities. These factors are used to calculate the gross return, cost of cultivation, net returnand benefit cost ratio. As a result, in comparison to farmers' practices (25848.00 Rs/ha), the average cost of cultivating both black and green grams during five consecutive years in Assam, Arunachal Pradesh and Sikkim increased on demonstration plots (28090.00 Rs/ha). Under improved technologies, crop green gram recorded highest net return of Rs. 86,644/ha in Sikkim followed by Assam (Rs. 29865/ha) and Arunachal Pradesh (Rs. 25170/ha) as compared to farmers' practices (Rs. 14,833) and (Rs 13,350) respectively. The results in Table 3 also indicates, both black gram and green gram showed higher benefit cost ratio (B:C ratio) of recommended practices in demonstration plots than control plot in all the three states. This could be because farmers are using better technologies and getting higher yields than they were using previously. Sikkim had the lowest B: C ratio (2.09) in black gram followed by Assam (2.33), while Sikkim reported the greatest B: C ratio (3.04) in green gram when compared to farmers' practices (2.56). These outcomes were consistent with the previous research conducted by Mauria *et al.* (2017). In all the years, the benefit-cost ratio under improved practices has outperformed farmers' practices. This could be because improved technologies provide larger yields than farmers' practices. The findings mentioned above were consistent with those of Mokidue *et al*. (2011); Kumar *et al.* (2017); Singha *et al*. (2020); Ojaha and Bisht (2020); Singh *et al*. (2020) and Gogoi *et al*. (2022).

Knowledge level of farmers

Table 4 showed that in Assam, the majority of farmers (58.60%) had a medium level of knowledge, while 14.0 per cent had a low level and 27.40 per cent had a high level. 57.40 per cent of farmers in Arunachal Pradesh had a medium level of knowledge, while (22.00%) had a low level and (20.60%) had a high level. In Sikkim, the majority of farmers (52.85%) had a high level of knowledge followed by high level of knowledge (31.42%) and low level 15.71%.

Improved practices adopted in pulses (Assam, Arunachal Pradesh and Sikkim)

Table 5 showed that 91.43 per cent farmers used quality seed in Sikkim whereas in Assam and Arunachal Pradesh 83.33 per cent and 76 per cent uses quality seed. Further 73.14 per cent optimum seed rate was observed in Sikkim followed by Assam (63.33 %) and Arunachal Pradesh (57.80%). Similarly in adoption of weed management, application of fertilizer and integrated pest management Sikkim recorded highest followed by Assam and Arunachal Pradesh. The adoption of these technology is recommended for the sustainable production of pulses in Northeast India.

Constraints in adoption of improved pulse production technology

Table 6 showed that problems of pest management, lack of marketing channel, lack of processing unit are the major constraint faced by the farmers in Assam followed by. In Arunachal Pradesh, the most common cause of problems is a lack of knowledge about management practices followed by problems of pest management and non-availability of quality seeds. In Sikkim, the most common causes are issues with pest management followed by lack of knowledge about management methods and lack of processing units.

Cluster frontline demonstrations in Assam, Arunachal Pradesh and Sikkim showed higher grain production output as compared to farmers' practices. Data revealed a notable

Table 4: Knowledge level of farmers (Assam, Arunachal Pradesh and Sikkim).

Level	Assam (n=1500)		Arunachal Pradesh (n=500)		Sikkim (n=350)	
	Frequency	%	Frequency	%	Frequency	%
Low	210	14.00	110	22.00	55	15.71
Medium	879	58.60	287	57.40	185	52.85
High	411	27.40	103	20.60	110	31.42

Table 5: Improved practices adopted in pulses (Assam, Arunachal Pradesh and Sikkim).

Technology	Assam (n= 1500)		Arunachal Pradesh (n=500)		Sikkim (n=350)	
	Frequency	%	Frequency	%	Frequency	%
Use of quality seed	1250	83.33	380	76.00	320	91.43
Seed rate	950	63.33	289	57.80	256	73.14
Weed management	750	50.00	247	49.40	180	51.43
Application of fertilizer	546	36.40	178	35.60	120	34.29
Use of integrated pest management	520	34.67	156	31.20	213	60.86

Table 6: Constraints in adoption of improved pulse production technology.

Constraints	Assam (n=1500)		Arunachal Pradesh (n= 500)		Sikkim (300)	
	%	Ranking	%	Ranking	%	Ranking
Non availability of quality seed	68.2	V	78.23	III	49.52	VI
lack of suitable variety of seeds	58.69	VI	75.96	IV	52.63	V
Lack of knowledge about management practices	71.23	IV	85.55	I	65.53	II
Problems of Pest Management	85.23	I	82.33	II	72.13	I
Lack of processing unit	76.96	III	62.12	V	62.33	III
Lack of marketing channel	82.33	II	58.33	VI	60.21	IV

rise in grain production under demonstration plots, showcasing the effects of advanced agricultural technologies. 8.37 q/ha was the average yield under the demonstration plots, surpassing the 6.06 q/ha recorded under farmers' practices. Sikkim exhibited the highest average yield in black gram, indicating a increase as compared to farmers' practices. Wide technological differences were found in three states, with the lowest in green gram (Arunachal Pradesh) and the greatest in black gram (Assam). Variability in soil fertility, rainfall, diseases, pests and geographical factors contributed to the observed technological gap. The technology index reflects the viability of the evolved technology on the farmer's field, a mean technology index was noted throughout the CFLD initiative, indicating the successful implementation of technical interventions. This outcome suggests that the effective performance of these intervention is likely to expedite the acceptance and implementation of demonstrated technological advancements. The benefit-cost ratio of cultivating field peas using improved practices consistently surpasses that of farmers' practices each year. This can be due to the higher output gained through the use of advanced technologies compared to traditional farming methods. The study emphasized that the adoption of a full package of practices, including high-yielding varieties and integrated pest management, contributed to higher yields in demonstration plots throughout the years, which was consistent with earlier research by various experts.

CONCLUSION

The preceding five-year data revealed that the integration of enhanced technology, together with active farmer participation had a favourable influence on increasing grain yield and economic return from pulse production in all three states of the north east region of India. The study found that, both the *kharif* pulses (black gram and green gram) produced more grain yield in recommended practices (CFLDs) than farmers' practices. Thus, cultivating *kharif* pulse crops with enhanced technologies, such as suitable varieties, nutrient and pest management has been shown to be more productive. The productivity gained under the programme created greater awareness and encouraged other farmers to implement appropriate production technologies. The study also concludes that there is a significant gap between the potential and demonstration yield primarily because of gaps in technology and extension as well as a lack of knowledge about newer better technologies. Cluster frontline demonstrations (CFLDs) provided a noteworthy good outcome and offered a chance to demonstrate the profitability and productivity potential of the newest technologies in actual farming situations. Hence, it is recommended that farmers may implement the improved agronomic practices embraced by the CFLD program in order to increase productivity and improve the economic return for the sustainable cultivation of pulse crops. Extension gaps and technological gaps might be filled by popularizing package of practices that prioritized the use of plant protection measures, nutrient management, improved crop variety seeds and proper seed rate *etc*.

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Conflict of interest

All authors declare that there is no conflict of interest.

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