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Science for resilient livelihoods in dry areas

Driving factors affecting the adoption of ICARDA-improved lentil varieties on lentil growers' livelihoods in West Bengal

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We provide innovative, science-based solutions to improve the livelihoods and resilience of resource-poor smallholder farmers. We do this through strategic partnerships, linking research to development, and capacity development, and by taking into account gender equality and the role of youth in transforming the non-tropical dry areas.

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Cover photo: Moitree variety (Lentil) plant given by ICARDA (West Bengal, India) © Soumitra Chatterjee, BKCV-2020

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Summary

Over the last six decades, there has been an unsatisfactory gain in pulse productivity in India, which is a severe threat to resilient livelihoods and the overall food and nutritional security of the country. Despite the launch of the National Food Security Mission (NFSM) in 2010, the initiative also failed to reach its target of increasing cereal and pulse production by at least 20 million tons by 2012.

In the same year, the International Centre for Agriculture Research in the Dry Areas (ICARDA) began to implement a multi-disciplinary project with the International Fund for Agricultural Development (IFAD) and Bidhan Chandra Krishi Viswavidyalaya (BCKV) to enhance lentil productivity under rice-based cropping systems in West Bengal, India. The project provided farmers with improved technologies, including 19 improved lentil varieties, and a package of agronomic practices to farmers.

This working paper documents the major constraints lentil growers faced in adopting ICARDA's improved lentil varieties, and increasing their knowledge, skills and good practices. It also outlines key findings about lentil prices and market dynamics at various stages of marketing, and assesses the lentil seed system. Finally, the paper provides suitable policy recommendations and identifies strategic actions to enhance the adoption and scalability of ICARDA's improved lentil varieties in West Bengal to boost farmers' productivity.

This study found that years of farming experience, along with a basic education level, were the prime drivers behind the overall adoption of new technology and quality seeds in West Bengal. Meanwhile, the unavailability of suitable and timely information brochures, pamphlets, leaflets, and news for growers meant that a significant proportion of farmers are still unaware about the new varieties and modern technology. Another hurdle faced by lentil farmers was the disparity between market margins (the difference between the price paid to the producer, and that paid by the consumer) in West Bengal. High market margins revealed high levels of interference by middlemen in some areas, resulting in price hikes for processed lentil.

One of the key recommendations to encourage uptake of the new varieties is to offer crop insurance to lentil farmers to protect them from losses resulting from natural calamities and boost their risk-bearing ability.

Key messages

1. The introduction of ICARDA's region-specific improved seeds and package of practices, for lentil producers, has had a positive economic impact in West Bengal since the project began in 2012.
2. Lentil productivity increased by 36% for farmers involved in ICARDA's project, with effective land preparation, use of quality seed, and implementation of better pest and disease management being the prime factors behind this success.
3. Years of farming experience and basic education level were found to be the prime contributors to farmers adopting ICARDA's improved seeds and practices, which enhanced the technical efficiency of farming families.
4. Whilst increased producer prices for lentil in West Bengal is welcome, most of the profit is found to be going to middlemen.

1. Introduction

Lentil is one of the most nutritious cool season food legume crops grown in India. Between 2012/13, when implementation of the ICARDA project began, the crop was grown on 1.14 million ha and produced 0.86 million tons, resulting in a productivity rate of 756.20 kg/ha (DES, 2013-14). In 2020/21, approximately half of the world's lentil production (48.2%) was cultivated in Southern Asia, but indigenous lentils in India are a specific ecotype (a genetically distinct geographic variety) with a marked lack of variability, poor germination rates and yields. In India, the indigenous varieties are primarily grown in northern and central regions, and both whole and dehulled lentils are used to make *dal* (a traditional dish), as well as other culinary preparations (Reddy, Bantilian and Mohan, 2013).

Lentils contain about 25% protein, 0.7% fat, 2.1% minerals, 0.7% fiber and 59% carbohydrate. Lentil is generally grown as a rainfed crop and, in West Bengal, the seeds are broadcast in a rice crop, seven to ten days before the rice is harvested (also known as *paira* cropping or relay cropping), to capitalize on the residual soil moisture content from growing rice, and ensure timely sowing and germination as tillage operations can be skipped.

There is tremendous potential to grow lentil as a cool season food legume in West Bengal, but productivity levels are low. During independence (1947/48), the productivity of all pulse crops grown in India was recorded at 567 kg/ha but, by 2011/12 (before ICARDA intervened), this had only increased to 699 kg/ha due to limited availability of suitable seed varieties.

Considering the crop's importance in terms of its nutritive value, productivity needs to be raised through using improved technologies and farming practices. ICARDA's multi-disciplinary project aimed to do this to boost farmer livelihoods and improve socio-economic development in West Bengal. This paper provides an insight into the factors driving the adoption of ICARDA-improved lentil varieties and identifies marketing channels that have the potential to strengthen the socio-economic development of farmers and farm households. With this aim, the study had the following objectives:

1. To document the major constraints lentil growers face in adopting ICARDA-improved varieties, and increasing their knowledge, skills and good practices.
2. To synthesize key findings about the price and market dynamics of lentil at various stages of marketing.
3. To assess the lentil seed system and identify problems and constraints.
4. To provide recommendations and identify strategic actions to enhance adoption and scalability of ICARDA-improved lentil varieties in West Bengal.

2. Major constraints of lentil cultivation

2.1 Delayed sowing of seeds

In general, lentil crop yields are significantly reduced if sowing is delayed beyond November. Late sowing negatively affects yield (Roy et al., 2009; Singh and Gupta, 2009; Gill 2013) due to disturbed phenological development (Erskine and Saxena 1993; Erskine et al., 1994), reduced sunlight (Gurung et al, 1996), low quality seeds and poor cultivation methods (Singh et al., 2017; Gill 2013), disrupted source to sink partitioning (Mishra et al., 1996; Turk et al., 2003), and shortened crop life cycle (Ramakrishna et al., 2000). Moreover, late sowing often results in cold injury occurring during seeding and early crop growth stages (Nadarajan and Chaturvedi,2010). Cool temperatures (-1.5°C to 15°C) during early growth crops stages (i.e. germination, seedling and vegetative stages) reduce seedling vigor, hamper crop establishment, increase susceptibility to soil-borne pathogens and hamper crop growth (Croser et al., 2003). Stunted plant growth also results in poor dry matter accumulation, which ultimately reduces grain weight and compromises productivity.

Many areas in West Bengal cultivate long duration *kharif* rice varieties, which often keep the land occupied until the mid to end of November, which then delays lentil sowing. Excessive soil moisture due to untimely rains during November and December can also further delay lentil sowing until mid-December.

2.2 Terminal heat stress

Delayed sowing can also lead to terminal heat stress, i.e. high temperature stress during the reproductive stage (Gaur et al., 2014). Terminal heat stress-induced damage in lentil includes floral and pod abortion, sterile pollen and ovules, compromised fertilization, and poor pod set and seed filling, which results in small and shriveled seeds (Gaur et al., 2014; Sita et al., 2017). High temperature-imposed senescence, also related to terminal heat stress, also shortens the crop life cycle by accelerating crop maturity, which results in seed yield reductions of up to50% (Gowda et al., 2013).

2.3 Terminal drought stress

Drought stress during reproductive and grain development stages is referred to as terminal drought (Fang et al., 2010; Farooq et al., 2017). Drought stress for lentil and other pulse crops has wide-ranging harmful impacts on flowering and podding biology including: reduced quantity of flowers with poor nectar (Al-Ghzawi et al., 2009); ii) flower abortion (Fang et al., 2010); iii) reduced net photosynthesis, which disrupts embryo development (Farooq et al., 2016); iv) poor pollen viability, infertile pollen grains (Farooq et al., 2016), reduced pollen germination and pollen tube growth (Gusmao et al., 2012); v) accumulation of non-reducing sugars and limited starch production (Farooq et al., 2016); vi) abscisic acid accumulation, which disturbs photosynthate partitioning resulting in pod abortion, and poor pod and seed set (Liu, Jensen and Andersen, 2004; Farooq et al., 2016); and, vii) a shortened crop cycle with a reduced reproductive development period (Daryanto et al., 2015), resulting in reduced seed yields.

2.4 Abiotic stress tolerance

- Uncertain rainfall is a serious abiotic constraint. Poor drainage/water stagnation during the rainy season causes heavy losses (due to low plant height) and increased incidence of blight disease (particularly in the states of Uttar Pradesh, Bihar, West Bengal, Chhattisgarh, Madhya Pradesh and Jharkhand). Since most pulse crops are drought tolerant, most research efforts have been confined to developing genotypes and associated production technologies to suit dry land conditions. Consequently, germplasm suited to high rainfall and irrigated conditions are lacking.
- After sowing, when plant height is about 10-12 cm, some plants tend to die in patches due to disease occurrence.
- Soil acidity is a serious constraint to lentil production in the *rabi* season – which can be detrimental to nodule fixation – as most pulses are highly sensitive to soil acidity compared to cereals and other non-pulses crops.
- Water-logging during seed germination and initial seeding growth phase is a constraint for lentils grown in rice fallows. High humidity during the vegetative growth stages (particularly during November to January) makes lentil susceptible to diseases such as Botrytis grey mold (BGM). The

appearance of BGM is more likely in years where excessive rainfall occurs during the winter, which can encourage excessive vegetative growth leading to lodging, and also encourage development of various leaf and root diseases.

2.5 Weed plant infestation

Lentils have slow vegetative growth in the early stages of crop growth and are a poor competitor to weeds (Siddique et al., 2012; Singh et al., 2017). Adoption of zero tillage, conservation agriculture-based technologies, and *paira* cropping further intensifies weed growth. These agronomic practices involve minimal to no soil disturbance and, as a consequence, weed seeds remain largely on the soil surface competing with lentils for natural resources. The extent of lentil yield reduction due to weed infestation has been reported to be as high as 50% (Rana et al., 2016), implying the severity of weed-induced losses, which could mean that losses could be even higher in conservation agriculture-based systems.

The dominant weeds that compete with lentils are *Chenopodium* sp., *Vicia* sp., *Avenas* sp., *Lathyrus tuberosus*, and wild rice. As well as competing with lentil for water and nutrients in the soil, weeds also negatively affect lentil productivity by acting as alternate hosts to insects, pathogens, and nematodes. While pre-emergence herbicide application is not possible in *paira* cropping systems, the use of post-emergence herbicides maybe a viable option to manage weed infestation.

2.6 Unavailability and poor quality of inputs

A lack of good quality and affordable lentil seeds, available at the right time (early to mid-October when sowing begins) is a major constraint. Not only does this lack of access limit production (traditional varieties yield between 500-600 kg/ha, while high-yielding seeds can reach up to 1,500 kg/ha), it is also one of the principal reasons behind crop failure (poor germination rates coupled with poor management practices). Timely availability of quality chemical fertilizers also continues to be a problem in many lentil-growing areas. While pesticide availability (including herbicides) in West Bengal has been reasonable, they are often of a poor quality and are not as effective which means more quantities are applied, which is detrimental to human and crop health.

2.7 Technological constraints

Legumes are grown under varied agro-climatic conditions (soil types, rainfall and thermal regime) in West Bengal. Yet, the availability of region-specific production technologies is lacking, including crop varieties with traits relevant to prevailing biotic and abiotic stresses and cropping sequences in the region.

Technological constraints include:

- Poor native rhizobium (soil bacteria) observed in 40% of West Bengal's pulse growing areas, which means that it is less efficient at fixing nitrogen in the soil (Reddy,2009). Yet seed inoculation with a suitable Rhizobium strain (which could boost lentil productivity by 10-12%) is not widely implemented. To be most effective, bio-fertilizers used on lentils should be based on modified strains of Rhizobium inoculum, isolated from regions with similar agro-climatic conditions.
- Insufficient irrigation. Despite an increase in irrigated area in India, cereals or cash crops are often prioritized, and pulses including lentils are relocated to rainfed areas which make these crops vulnerable to biotic and abiotic stresses. Currently, only 12% of the irrigated area in West Bengal is currently under pulses while, under wheat and paddy, the irrigated area is more than 60% of the total cropping area (Reddy and Reddy, 2010).
- Low seed rate, improper sowing methods, and sowing under *paira* cropping without proper agronomic management practices, are stunting productivity of pulses in India.

2.8 Credit and policy-related constraints

Marginal farmers are most likely to be engaged in lentil cultivation. With limited resources, marginal farmers struggle to access credit to invest in their crops. Markets are also fragmented and infrastructure for storage and post-harvest processing near production areas is lacking. Consequently, most farmers sell their produce at a very low price to local village traders.

2.9 Varietal constraints

A lack of access to high-yielding, short-duration varieties means that most farmers plant traditional varieties. These traditional varieties have a low harvest index (the ratio of grain to total dry matter; used as a measure of productivity), are susceptible to pests and diseases, have intermediate growth habits, do not respond well to inputs, and have unstable performances.

2.10 Unavailability of suitable information

There is a lack of informative and timely brochures, pamphlets, leaflets, and news about new varieties and better inputs, and the benefits of using modern varieties for farmers in West Bengal. Farmers are often illiterate, and with little access to information are therefore unaware about new varieties and modern technologies that could be used to boost their lentil production.

2.11 Risk adverse

Small farmers are less able to take a risk on adopting improved technologies, and the risks involved in growing lentils are not compensated under the Minimum Support Price (MSP, designed to ensure that harvest prices for other crops are higher than the production costs).

3. Research methodology

3.1 Identification of key constraints with regards to lentil cultivation

To identify and prioritize the key constraints regarding region-based wide-scale adoption of lentil seed, 12major issues were considered and analyzed. These were:

X1 = Lack of knowledge about improved seeds and their practices
X2 = Unavailability of quality seeds
X3 = Susceptibility of varieties to disease/pests
X4 = Farmers' perceptions about the performance of modern lentil varieties
X5 = Late crop maturity
X6 = Lack of farmers' knowledge about fertilizers and pesticides application
X7 = Recommended fertilizers not available in local markets
X8 = No knowledge of soil testing
X9 = Information brochures/pamphlets unavailable
X10 = Farm problems taken to research stations/ university/extension not solved
X11 = Lack of insurance schemes
X12 = Lack of capital

The extent of the constraints was quantified and categorized into five levels:

1. Very low: 0
2. Low: 1
3. Moderate: 2
4. High: 3
5. Very high: 4

Principal Component Analysis (PCA), along with hierarchical and K-means cluster algorithms, were used to analyze75 ICARDA farm households to identify the variability of each constraint, as well as to prioritize and categorize farm households according to the key constraints faced in lentil cultivation.

3.2 Market dynamics

Regional market dynamics and price movements from producer (farmers that had used ICARDA-improved varieties) to final consumer were also studied by implementing surveys across West Bengal in 2020/21. The price movements were classified as:

Farm gate price (producer price) → agent collection price → dehulled lentil price to dealer/distributor → wholesale price → retail price (consumer price).

In addition, the market margin of lentil seeds across various markets in West Bengal were calculated for different ICARDA-improved varieties.

Market margin = [producer price – consumer price].

4. Results and discussions

4.1 Results of constraints of lentil cultivation faced by farm households

Table 1 shows that there is a correlation within the constraints, as susceptibility to disease/pest incidence (X3) creates a negative and significant impact on a farmers (negative) perception about the performance of modern lentil varieties (X4), which can affect the overall adoption of suitable varieties by growers. A lack of informative brochures and pamphlets (X9) has a negative impact on the perception of farmers about the performance of modern varieties (X4); most farmers in West Bengal are generally not yet aware of the availability of new varieties and modern cultivation technology.

Late lentil crop maturity (X5) is correlated with the unavailability of recommended NPK in the market (X7), likely because a lack of fertilizer application at the correct time will lead to late crop maturity. There is also a significant inverse relationship between crop insurance (X11) and the unavailability of recommended NPK in the market (x7). Complicated insurance procedures, or a lack of insurance if crops fail, mean that growers often struggle to access agricultural inputs at the right time.

After performing PCA for 12 constraint variables (Table 2), the first eight had shown 100% variability of the data. This means that the remaining four were excluded. The results revealed that two variables – recommended fertilizers not available in local markets (X7) and a lack of suitable insurance schemes (X11) – resulted in a significant positive and negative impact score, respectively. Unavailability of suitable information brochures, leaflets and pamphlets (X9) dominated Principal Component 2 and 3, while X3 (disease/pest susceptibility) showed significant dominance in Principal Component 3, 6 and 7. X1 (lack of knowledge about improved seeds and their practices) dominated in Principal Component 5 and 6, while X4 (perception about the performance of modern lentil varieties) dominated Principal Component 6 and 7, and X6 (lack of knowledge about fertilizers and pesticides application) dominated Principal Component 7 and 8.

Regarding K-means cluster analysis, the various constraints were divided into five distinct clusters (Table 4), formed according to homogeneity of choice and preferences of ICARDA's sample lentil growers. Out of 75 farm households surveyed for constraint analysis across different regions in the state, 27 farm households belong to Cluster 1, 30 belongs to Cluster 2, ten households belong to Cluster 3, three households belong to Cluster 4, and five households belong to Cluster 5. The distribution of clusters are highly significant for X5 (late crop maturity), X7 (recommended NPK fertilizers not available in local markets), and X9 (unavailability of information brochure, leaflet, pamphlet etc.) (Table 6), meaning that data distribution has a significant impact on clustering results.

4.2 Results of market dynamics

The change in price of lentils at various marketing stages was collected through a market survey across different locations in West Bengal. Table 8 reveals that the market margin for lentil ranges between Rs. 50-65 per kg at different markets in Hooghly, compared to Rs. 50 per kg for Murshidabad and Rs. 40-45 per kg in Nadia. The market margin is highest in markets in Bankura District, ranging between Rs. 60-70 per kg. In 24-Parganas (N), the market margin ranges between Rs. 65-75 per kg, in Haringhatait is between Rs. 30-55 per kg, and in North Bengal it is between Rs. 45-60 per kg. The higher market margins in some markets are likely to be caused by middlemen hiking prices, which reveals why region-wide information about lentil marketing should be made more widely available for farmers.

Providing farmer cooperatives with dehuller machines will also help farmers to process lentil and sell the processed products, which will add value and increase the percentage farmers can earn from the money consumers spend on lentils by around 40%. This will enhance farmer incomes and boost interest from other farmers in lentil production.

Table 1. Correlation matrix of constraints faced by farm households.

Constraints	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1.000	-	-0.031^{NS}	-0.013^{NS}	0.029^{NS}	0.025^{NS}	-0.027^{NS}	-	-0.033^{NS}	-	0.173^{NS}	-
X2		-	-	-	-	-	-	-	-	-	-	-
X3			1.000	**-0.233***	-0.127^{NS}	-0.166^{NS}	-0.054^{NS}	-	-0.076^{NS}	-	-0.194^{NS}	-
X4				1.000	-0.163^{NS}	0.008^{NS}	-0.013^{NS}	-	**0.291***	-	-0.077^{NS}	-
X5					1.000	-0.102^{NS}	**0.289***	-	-0.015^{NS}	-	-0.119^{NS}	-
X6						1.000	-0.182^{NS}	-	-0.013^{NS}	-	0.217^{NS}	-
X7							1.000	-	0.041^{NS}	-	**-0.291***	-
X8								-	-	-	-	-
X9									1.000	-	0.032^{NS}	-
X10										-	-	-
X11											1.000	-
X12												-

Note: * means significant at $p_{0.05}$ level; NS means non-significant

Table 2. Eigen-values of the covariance matrix.

Components	Eigen-value	Difference	Proportion	Cumulative
X1	0.604	0.169	0.3129	0.3129
X2	0.435	0.201	0.2251	0.5380
X3	0.234	0.019	0.1212	**0.6593**
X4	0.214	0.050	0.1111	0.7704
X5	0.164	0.019	0.0851	0.8555
X6	0.144	0.073	0.0749	0.9304
X7	0.072	0.008	0.0371	0.9675
X8	0.063	0.063	0.0325	1.0000
X9	0.000	0.000	0.0000	1.0000
X10	0.000	0.000	0.0000	1.0000
X11	0.000	0.000	0.0000	1.0000
X12	0.000	0.000	0.0000	1.0000

Table 3. Component-wise Eigenvectors of constraints.

	Prin1	Prin2	Prin3	Prin4	Prin5	Prin6	Prin7	Prin8	Prin9	Prin10	Prin11	Prin12
X1	-.022031	-.026258	-.038852	0.251420	**0.875007**	**0.366358**	**-.152531**	0.104799	0.00000	0.00000	0.00000	0.00000
X2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.00000	0.00000	0.00000	0.00000
X3	-.044514	**-.158426**	**0.444721**	**-.596116**	0.034104	**0.523594**	**0.379741**	-.016498	0.00000	0.00000	0.00000	0.00000
X4	-.012598	0.496902	**-.688143**	-.122817	-.124457	**0.448504**	**0.208948**	-.063247	0.00000	0.00000	0.00000	0.00000
X5	0.259558	-.104347	0.228303	**0.692931**	**-.356049**	0.481828	**0.174613**	-.006780	0.00000	0.00000	0.00000	0.00000
X6	-.076680	0.012994	-.062522	0.096858	0.054464	**-.210289**	**0.541521**	**0.800143**	0.00000	0.00000	0.00000	0.00000
X7	**0.948972**	-.032833	-.094974	-.178762	0.152655	-.144683	0.113094	-.019261	0.00000	0.00000	0.00000	0.00000
X8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.00000	0.00000	0.00000	1.00000
X9	0.071767	**0.845422**	**0.511971**	0.040297	0.061832	-.089899	-.055159	0.037771	0.00000	0.00000	0.00000	0.00000
X10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.00000	1.00000	0.00000	0.00000
X11	**-.135741**	0.020675	0.002916	0.207930	0.246671	**-.291685**	**0.670302**	**-.585382**	0.00000	0.00000	0.00000	0.00000
X12	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.00000	0.00000	1.00000	0.00000

Figure 1. Scree plot of variance explained in different principal components.

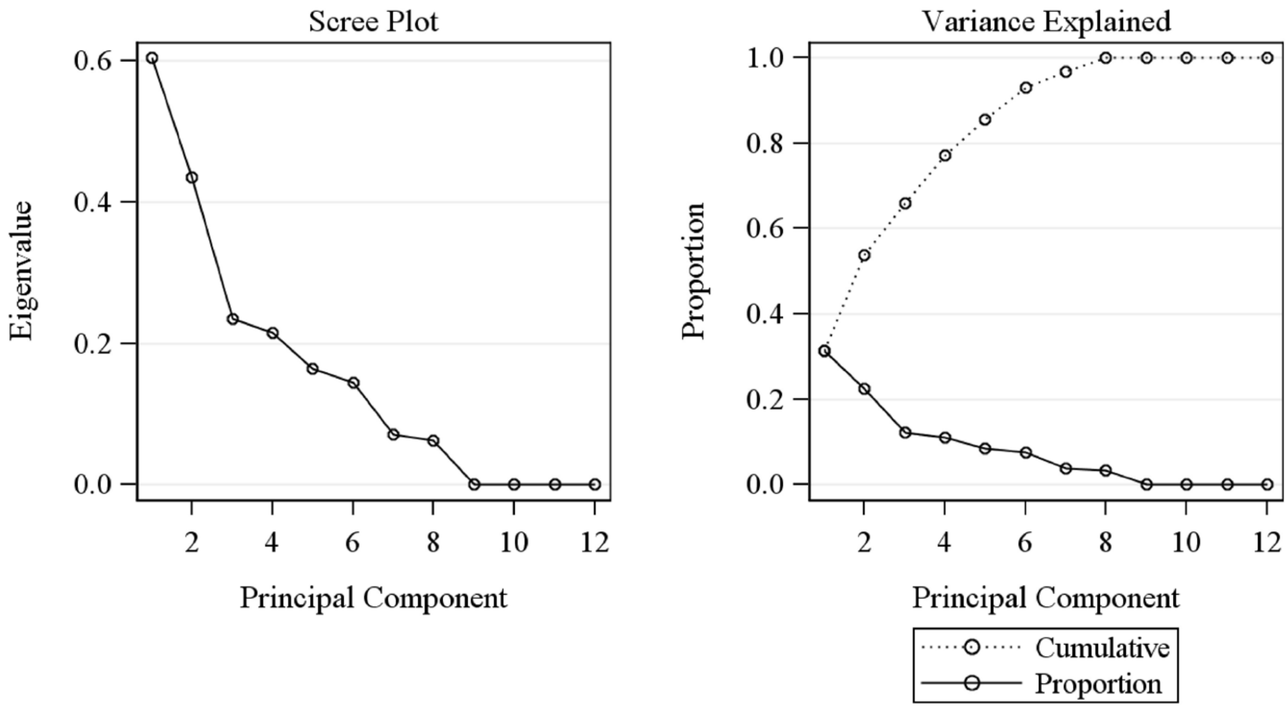

Figure 2. Distribution of component scores among sample ICARDA farm households.

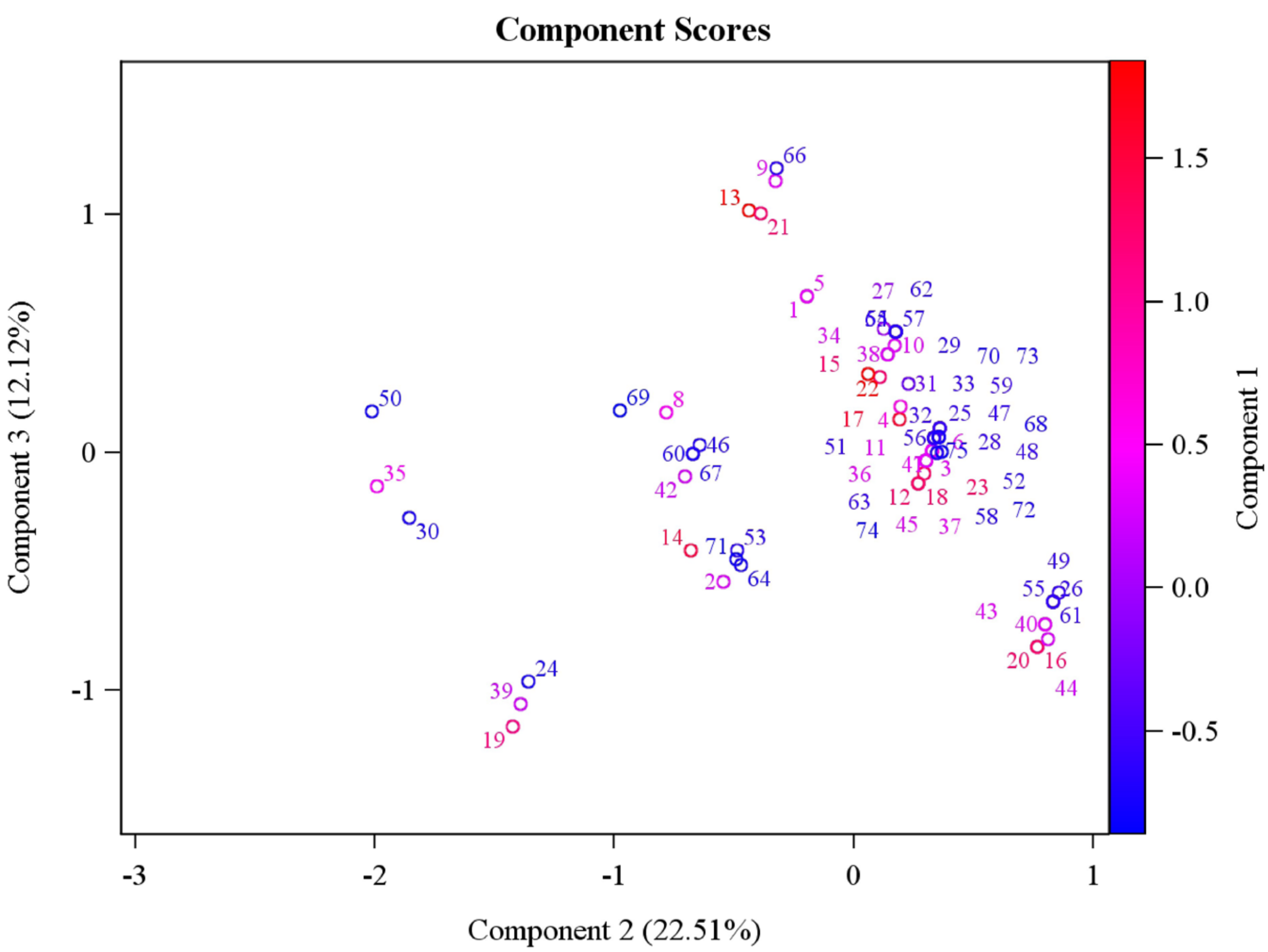

Table 4. Final cluster centers.

	Cluster				
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
X1	3.74	3.87	3.70	3.67	4.00
X2	2.00	2.00	2.00	2.00	2.00
X3	1.30	1.20	1.40	1.00	1.00
X4	3.04	3.10	2.70	2.67	2.80
X5	.07	.10	.00	1.67	.40
X6	2.04	2.10	2.20	2.00	2.00
X7	3.26	2.00	2.00	4.00	3.40
X8	4.00	4.00	4.00	4.00	4.00
X9	1.93	2.00	.70	2.00	.40
X10	2.00	2.00	2.00	2.00	2.00
X11	3.00	3.20	3.20	3.00	3.00
X12	4.00	4.00	4.00	4.00	4.00

Table 5. Distance between final cluster centers.

Cluster	1	2	3	4	5
1		1.290	1.813	1.823	1.633
2	1.290		1.392	2.602	2.193
3	1.813	1.392		2.951	1.597
4	1.823	2.602	2.951		2.157
5	1.633	2.193	1.597	2.157	

Table 6. ANOVA.

	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
X1	.145	4	.163	70	.891	.474
X2	.000	4	.000	70	.	.
X3	.213	4	.183	70	1.160	.336
X4	.439	4	.246	70	1.785	.142
X5	1.915	4	.120	70	15.926	.000
X6	.064	4	.075	70	.855	.496
X7	8.790	4	.091	70	96.368	.000
X8	.000	4	.000	70	.	.
X9	5.699	4	.074	70	77.430	.000
X10	.000	4	.000	70	.	.
X11	.187	4	.091	70	2.042	.098
X12	.000	4	.000	70	.	.

Note: The 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 7. Number of cases in each cluster.

Cluster	1	27.000
	2	30.000
	3	10.000
	4	3.000
	5	5.000
Valid		75.000
Missing		.000

Dendrogram.

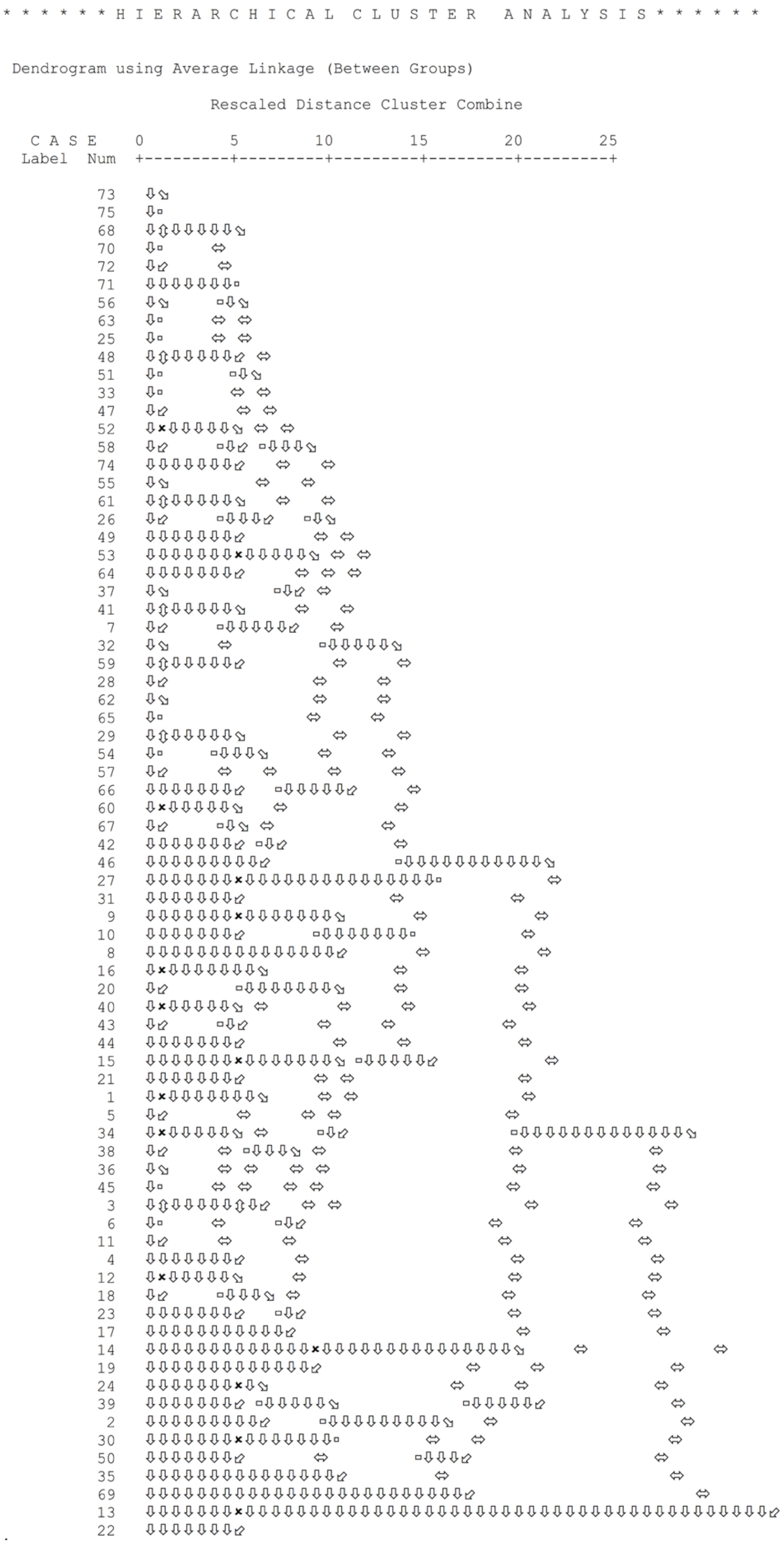
* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *
Dendrogram using Average Linkage (Between Groups)
Rescaled Distance Cluster Combine
C A S E   0   5   10   15   20   25
Label   Num
73 75 68 70 72 71 56 63 25 48 51 33 47 52 58 74 55 61 26 49 53 64 37 41 7 32 59 28 62 65 29 54 57 66 60 67 42 46 27 31 9 10 8 16 20 40 43 44 15 21 1 5 34 38 36 45 3 6 11 4 12 18 23 17 14 19 24 39 2 30 50 35 69 13 22

Table 8. Market dynamics and price spread of lentil varieties across different regions of West Bengal.

Variety	Particulars	Balagarh	Goghat	Kota	Bhagawangola	Harekrishnapur
		Hooghly			Murshidabad	Nadia
HULL-57	Farm gate price	Rs. 50-55 per kg	Rs. 60 per kg	Rs. 65 per kg	Rs. 70 per kg	Rs. 75 per kg
	Agent collection price	Rs. 60 per kg	NA	Rs. 67 per kg	Rs. 72 per kg	Rs. 77 per kg
	Dehulled lentil sold to dealer price	Rs. 70-75 per kg	Rs. 85-90 per kg	Rs. 75-80 per kg	Rs. 90-95 per kg	Rs. 95 per kg
	Wholesale price	NA	NA	Rs. 110 per kg	Rs. 110 per kg	Rs. 100-105 per kg
	Retail price	Rs. 110-120 per kg	Rs. 110-120 per kg	Rs. 120 per kg	Rs. 120 per kg	Rs. 115-120 per kg
Market margin		**Rs. 60-65 per kg**	**Rs. 50-60 per kg**	**Rs. 55 per kg**	**Rs. 50 per kg**	**Rs. 40-45 per kg**

Variety	Particulars	Layekdihi	Dahala	Laltoragobindosol	Lachmanpur
		Bankura			
HULL-57	Farm gate price	Rs. 50-55 per kg	Rs. 50-55 per kg	Rs. 50 per kg	Rs. 50 per kg
	Agent collection price	Rs. 60 per kg	Rs. 62 per kg	Rs. 55-60 per kg	Rs. 55-60 per kg
	Dehulled lentil sold to dealer price	Rs. 85-90 per kg	Rs. 85-90 per kg	Rs. 90-95 per kg	Rs. 90-95 per kg
	Wholesale price	Rs. 100 per kg	Rs. 100 per kg	Rs. 100-110 per kg	Rs. 100-110 per kg
	Retail price	Rs. 110-120 per kg	Rs. 120 per kg	Rs. 115-120 per kg	Rs. 115-120 per kg
Market margin		**Rs. 60-65 per kg**	**Rs. 65-70 per kg**	**Rs. 65-70 per kg**	**Rs. 65-70 per kg**

Variety	Particulars	Hasnabad
		24 Parganas (N)
L-4717	Farm gate price	Rs. 55 per kg
	Agent collection price	Rs. 60-65 per kg
	Dehulled lentil sold to dealer price	Rs. 90-95 per kg
	Wholesale price	Rs. 100-105 per kg
	Retail price	Rs. 110-120 per kg
Market margin		**Rs. 65-75 per kg**

Variety	Particulars	Bizra	Dakalipara	Chapra Dhantola	Kurumbelia
		Nadia			
PL-406	Farm gate price	Rs. 72 per kg	Rs. 75 per kg	Rs. 70 per kg	Rs. 65 per kg
	Agent collection price	Rs. 75 per kg	Rs. 80 per kg	N/A	Rs. 70 per kg
	Dehulled lentil sold to dealer price	Rs. 90-95 per kg	Rs. 85-90 per kg	Rs. 85-90 per kg	Rs. 80-90 per kg
	Wholesale price	Rs. 100-105 per kg	N/A	Rs. 110-115 per kg	Rs. 100-105 per kg
	Retail price	Rs. 115-120 per kg	Rs. 105-110 per kg	Rs. 120 per kg	Rs. 110-120 per kg
Market margin		**Rs. 43-48 per kg**	**Rs. 30-35 per kg**	**Rs. 50 per kg**	**Rs. 45-55 per kg**

Variety	Particulars	Gajol	Chachol	Balurghat
		North Bengal		
BM-7 (Barimusur)	Farm gate price	Rs. 60-65 per kg	Rs. 70 per kg	Rs. 65 per kg
	Agent collection price	Rs. 70 per kg	Rs. 77 per kg	Rs. 75 per kg
	Dehulled lentil sold to dealer price	Rs. 90-95 per kg	Rs. 90-95 per kg	Rs. 90-95 per kg
	Wholesale price	Rs. 100-110 per kg	Rs. 100-110 per kg	Rs. 100-110 per kg
	Retail price	Rs. 115-120 per kg	Rs. 115-120 per kg	Rs. 115-120 per kg
Market margin		**Rs. 55-60 per kg**	**Rs. 45-50 per kg**	**Rs. 50-55 per kg**

5. Conclusion and summary

This paper concludes that a lack of knowledge about improved seeds and good agricultural practices, followed by the unavailability of quality seeds jointly were a constraint for 53.8% of farmers (Table 2). Susceptibility to disease/pest incidence negatively impacts the perception farmers have about the performance of modern lentil varieties (Table 1). Small farmers, who have less risk-bearing ability, can be easily dissuaded from growing a new variety if there is doubt about its effectiveness, which may affect the overall adoption of suitable varieties by growers. A lack of appropriate information for farmers in West Bengal also results in farmers not being aware of new varieties and technologies.

The unavailability of recommended NPK fertilizers also has a direct impact on farmers, resulting in late crop maturity of lentil due to delayed sowing. A link was also found between crop insurance and the unavailability of NPK, suggesting that complicated insurance procedures, or a lack of insurance, was hampering farmers' ability to have the available credit to purchase agricultural inputs at the right time. Crop insurance scheme for growers should therefore be strengthened for all pulse crops, to protect farmers from losses resulting from natural calamities, and boost their risk-taking ability.

5.1 Demand and supply scenario of pulses in India

India's rank in pulse productivity is 24th, 9th, 23rd, 104th, 52th in chickpea, pigeon pea, lentil, dry bean and field pea, respectively. Despite pulse production increasing by 3.45% per annum during 2000-10, before ICARDA's intervention, increases in production costs and supply constraints also pushed lentil prices so high that they became unaffordable for most consumers. The overall growth rate for area, production and productivity of pulses also remained very low (0.06%, 0.65% and 0.59%) compared to cereals. Consequently, India imports 3-4 million tons of pulses every year to meet domestic demand.

During the 1980s, there was negative growth in the total area of pulses, and growth in production and yield was 1.52% and 1.61%, respectively. During 2000/01 to 2011/12, the indices of area, production and yield of pulses grew by 1.70%, 3.47%, and 1.91%, respectively. During April 2012 to July 2015, gram/chickpea prices were higher in India's wholesale domestic market than the international market, while domestic prices for Tur/Arhar were also higher than international prices between February 2013 and 2015. Between September 2012 and June 2015, price fluctuations in international markets were greater for lentil, green gram and urd bean than in the domestic market (Department of Agriculture & Farmers Welfare, 2016). Since January 2015, the Wholesale Price Index of pulses, vis-à-vis cereals and food articles, indicates a double digit trend, crossing 30% change during June and July 2015, so in comparison to pulses in the same period, the rate of inflation for cereals has been very low and for food articles has been moderate.

5.2 Price policy and market price in India

Lentil markets are volatile and fragmented. While market prices have increased over the last decade, production yields have not, due to a lack of investment in inputs and risky rainfed conditions, which lead to lentil crop vulnerability due to biotic and abiotic stresses. Lentil farmers sell their produce to local village traders at a low price, which is then sold to processors and ultimately to rural/urban consumers. There is no marketing infrastructure for storage, warehousing, post-harvest processing or milling near production centers.

The risks involved in growing pulses are not compensated by the MSP. The MSP of Rs 5,500 per 100 kg in 2022-23for lentil is much higher than the MSP of Rs 1,080 per 100 kg for paddy. But while paddy yields are about 3,000 kg/ha, pulses have a national average yield of 600 kg/ha. Differences between the MSP and the price on the open market also reveals the impact that middlemen have on the market. For example, when market prices of pigeon pea were above Rs 100/kg, the MSP was Rs 23/kg.

From 2005 to 2010, pulse prices consistently increased, thereafter, up to 2012, there was downward trend except for chickpea, but chickpea prices steeply decreased after 2012/13 before rising again, while mung bean and urd bean prices have been rising since 2013. Price indices of chickpea are always moderate compared to other pulse crops, except between 2012 and 2013.

The spike in the chickpea prices during 2012 was mainly due to high world prices; thereafter domestic prices were higher than global prices due to a short supply and a higher MSP, although overall both domestic and world prices moderated after 2012.

There has been an upward movement in the prices of most pulses. The price of pigeon pea, mung bean and urd bean has generally been rising, and has seen little fluctuation, while lentil prices have had higher levels of fluctuation as they have risen. Peaks in prices have also been seen; in 2006, there was a surge in imports of pulses and high global prices continued.

In 2012, high MSP and world prices, along with the depreciation of the Indian rupee led to elevated pulse prices. Compared to total pulse requirements of 18.33 million tons for 2009–10, domestic production in 2012 was only 14.6 million tons. Annual imports of 2-3 million tons provides only partial relief and led to escalation in the market price.

By 2050, the domestic requirement of pulses is estimated to be 26.5 million tons, which requires increasing pulse production by 81.5% (11.9 million tons of additional produce, at an annual growth rate of 1.86%. The additional production will require productivity enhancement (to produce 7.9 million tons), and area expansion (2.5 million tons) (Singh, Shahi and Singh, 2017).

The growth rate of pulse production has fluctuated, from being 1.52% in the 1980s, and 0.59% in the 1990s, to 1.42% during 2001-08, and 0.6%in 2020/21. Meanwhile, the growth rate of the total area under pulse production was negative in the 1980s and 1990s. If the area remains constant, as seen during the last four decades, a 2.05% annual growth rate in productivity will be required to produce 26.5 million tons by 2050. This will only be achieved if farmers have access to appropriate technology and training, and the promotion of pulse production is prioritized by national policymakers.

5.3 Future strategies for enhancing production and productivity of pulses in West Bengal

To achieve self-sufficiency in all pulse crops by 2025, an estimated 27.5 million tons needs to be produced each year. In addition to reducing post-harvest losses, productivity also needs to be enhanced from 897 kg/ha in West Bengal (DES, 2020/21) to at least 1,000 kg/ha, and an additional area of 3-4 million ha needs to be brought under pulses (Ali and Kumar, 2005; ICAR, 2014). Achieving these ambitious aims will require a proactive strategy from researchers, planners, policymakers, extension workers, the private sector, and farmers to boost productivity and reduce production costs.

Some region-specific key strategies need to be implemented to enhance overall pulse productivity in India. These are as follows:

A) Developing input responsive and non-lodging varieties, and short duration varieties

These would mitigate problems like germination loss and yield loss due to environmental factors, such as untimely rains, cyclones etc., which specifically occur during the harvesting season, causing huge production losses.

B) Development of extra-short duration genotypes (< 120 days maturity) of lentil

Introduction of early maturing lentil varieties (L-4717: maturity in 105-107 days) is highly recommended by the government; a shorter vegetative phase and early flowering also results in higher yields. L-4717 has been widely adopted in various parts of West Bengal, particularly for seed production in Hooghly Goghat-I block, but the block in general is mono-cropped and dependent on the winter *rabi* season. So research needs to be particularly targeted at different blocks to raise the livelihoods of pulse farmers.

C) Early-maturing varieties for rice fallow areas

A substantial proportion of lentils are sown late in rice fallow fields on the Indo-Gangetic plains. Early-maturing lentil varieties, which possess a high biomass and tolerance to high temperatures at the reproductive stage are required. Varieties should also have resistance to diseases like stemphylium blight, rust and wilt; tolerance to low temperatures at the vegetative stage and high temperatures at reproductive stage, and terminal soil moisture stress are also desirable.

D) Development of abiotic stress tolerant varieties

Some region-specific suitable abiotic stress-tolerant varieties of lentil and other pulses need to be introduced to raise overall pulse productivity in India.

Production and productivity of pulses in India

In 2011, chickpea production exceeded 8 million tons for the first time and cropping area reached 9.2 million ha, which was~0.4 million ha less than the highest chickpea area recorded in 1962 (~9.57 million ha). During 1965/67 to 2010/12, the chickpea area declined drastically from 4.7 to 0.7 million ha in northern states like Punjab, Haryana and Uttar Pradesh, while it increased from 2.1 to 6.1 million ha in central and southern states of Madhya Pradesh, Maharashtra, Andhra Pradesh and Karnataka. Pigeon pea was cultivated on 4.65 million ha, with a production of 3.02 million tons, and a yield of 650 kg/ha during 2013.

Lentil, one of the most nutritious cool season pulses grown in northern and central India, was cultivated on 1.42 million ha in 2012/13 with a productivity of 1.13 million tons. In the last two decades, the area under lentil has increased by 28% and production by 24% with a productivity increase of 6%.

In 2012/13, green gram or mung bean had a yield of 1.19 million tons, from 2.71 million ha. With the development of short duration and disease-resistant varieties, its cultivation during the spring/summer season (Singh et al., 2017) is gaining popularity in most parts of country.

Urd bean cultivation increased from 1.87 million ha in 1971/72 to 3.11 million ha during 2012/13 with production levels of 1.90 million tons. This increase in production is mainly attributed to the additional area brought under production, as well as productivity gains (from 0.5 to 1.3 t/ha). Summer cultivation in northern India and winter cultivation in rice fallows in southern and coastal areas also added to additional acreage.

Field pea, another important *rabi* pulse crop, is grown on about 0.76 million ha with an annual production of 0.84 million tons; a productivity of >1.1 t/ha during 2012/13. The crop's cultivation is also confined to rainfed, marginal and sub-marginal lands with poor soil fertility, however, with the development of input responsive dwarf type varieties, farmers often irrigate the crop to achieve higher yields in central and northern India.

E) Development of biotic stress tolerant varieties

Lentil suffers substantial yield losses from various biotic stresses (including BGM, pea seed-borne mosaic virus, pea enation mosaic virus, anthracnose, Stemphylium blight, Ascochyta blight, rust, powdery mildew, fusarium wilt, and root-knot nematodes). Previous efforts have been directed towards developing improved varieties with resistance to one or more biotic stresses, improving seed size and shortening the crop duration to fit lentil in various cropping systems. In the last decade, lentil production and productivity have stagnated in South Asia. To break the current yield plateau in lentil, there is a need to develop extra short duration varieties for rice-based systems for South Asia, drought- and heat-tolerant varieties with multiple disease resistance for all the regions, and herbicide-tolerant and machine harvestable varieties. This requires comprehensive research to develop a strategy involving both conventional and genomic breeding tools (Kumar et al., 2013).

F) Use of molecular technologies and transgenics to develop suitable germplasm

Pyramiding of genes for resistance to major insect pests (thrips, jassids and pod borer) and diseases (yellow mosaic virus, anthracnose, powdery mildew, Cercospora leaf spot, etc.) – for which high level of resistance is not available in cultivated germplasm – and identification of diverse germplasm held by donors, is of paramount importance. Pyramiding of useful genes to develop multiple stress-resistant varieties is needed through the deployment of molecular markers in breeding programs. Similarly, incorporation of bruchid resistance will help in minimizing post-harvest losses during storage. For a major breakthrough in yield, there is an urgent need to: broaden the genetic base of pulses by strengthening pre-breeding and developing core sets of germplasm; harness hybrid vigor through the development of cytoplasmic-nuclear male-sterility (CMS)-based hybrids in pigeon pea; map and tag genes/quantitative trait loci (QTL) and marker assisted selection for resistance to insect pests and diseases, yield and grain quality;

implement gene pyramiding for stable resistance; develop transgenics for problems as yet unsolved through conventional means (Helicoverpa pod borer and drought), and genomic research for understanding the structure and function of genes. High yielding and input-responsive genes are yet to be searched and transgressed in common varieties.

G) Bring additional areas under pulse production
The scope for introducing pulse crops in rice-fallows (mostly un-irrigated) needs to be exploited with supplemental irrigation. There is vast area of fallow land in West Bengal (1.7 million ha), with most suitable for pulse cultivation. A national task force on pulses, created in 2015 by Dr Alagh, has already identified the areas with the greatest potential for expansion (Reddy, 2015). The recommendations from the pulse taskforce include:

1. Utilize rice fallow land (3 to 4 million ha) in eastern India. This would yield around 2.5 million tons of pulse each year.
2. Diversify 500,000 ha of low-yielding upland rice, 450,000 ha of millet and 300,000 ha of barley, mustard and wheat, by bringing these areas under *rabi* pulses.
3. About 1.65 million ha vacated by wheat, peas, potato and sugarcane production can be used to grow 60-65 day summer mung bean crops in states (including West Bengal) where adequate irrigation facilities exist and intercropping in specific agro-climatic regimes is identified (Singh et al., 2017).

ICARDA's input-responsive, non-lodging and short duration lentil varieties have proven to be successful in West Bengal. In rice-fallow areas, ICARDA varieties are recommended 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).

Hull-57: Adopted by 171 farm households in Hooghly (Balagarh, Kota, Goghat–I and II), Murshidabad (Bhagabangola), Nadia (Harekrishnapur) and Bankura (Gangajalghati, Khatra, Indpur, Chhatna, Jhilmili) districts
Mean yield: 1,350 kg/ha
Return cost ratio: 2.20
Prime contributor: Quality seed, human labor and organic manure

PL-406: Adopted by 89 farm households in Nadia (Chapra Dhantola, Bizra, Kurumbelia, Dakalipara) District
Mean yield: 780 kg/ha
Return cost ratio: 1.49
Prime contributor: Human labor, mechanization, application of inorganic fertilizer (NPK)

L-4717 (Early): Adopted by 24 farm households in 24-Parganas North District
Mean yield: 2,150 kg/ha
Return cost ratio: 2.86
Prime contributor: Quality seed

Barimusur-7: Adopted by 56 farm households in North Bengal districts of Malda (Gajol, Chanchol) and Dinajpur South (Balurghat)
Mean yield: 850 kg/ha
Return cost ratio: 1.51
Prime contributor: Human labor and mechanization

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