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Ensuring productivity advantages through Cluster Frontline Demonstrations (CFLD)-pulses: Nationwide experiences

ATAR SINGH[1], A K SINGH[2], S K DUBEY[1]*, V P CHAHAL[2], RANDHIR SINGH[2], ANUPAM MISHRA[3], RAJBIR SINGH[4], B C DEKA[5], S K SINGH[6], S S SINGH[7], LAKHAN SINGH[8], A K TRIPATHI[9], Y G PRASAD[10], ANJANI KUMAR[11], M J CHANDRA GOWDA[12], SADHNA PANDEY[1] and RAJEEV SINGH[1]

ICAR-Agriculture Technology Application Research Institute, Kanpur, Uttar Pradesh 208 002, India

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ABSTRACT

The present study is the analysis of large scale data (31949 ha area and 79873 farmers) generated through the CFLD on pulses across the major pulses growing states under the ICAR-ATARIs of Kanpur (Uttar Pradesh), Jodhpur (Rajasthan), Pune (Maharashtra), Patna (Bihar), Jabalpur (Madhya Pradesh), Kolkata (West Bengal), Guwahati (Assam), Shillong (Meghalaya), Hyderabad (Andhra Pradesh), Bengaluru (Karnataka) and Patna (Bihar). The pulse crops included in this analysis were from all three growing seasons: *kharif* (pigeonpea-5556 ha, blackgram-6067 ha, and greengram-2689 ha), *rabi* (chickpea-8376 ha, lentil-3747 ha and field pea-1890 ha), and summer (greengram-3624 ha). The average performance data of CFLD were obtained for the above states for all the crops representing all three growing seasons during the cropping seasons of 2016–17 and 2017–18. Thus, CFLD data were analyzed from across minimum of 21 states (greengram) and maximum of 24 states (blackgram). The major variables analyzed were average yield obtained from the check plots and demonstrations plots. These yields were computed for yield advantages and also compared with the reported district level, state level, national level yields and the potential yields of the respective crops in the given states (data procured from secondary sources for the year 2017–18). Accordingly, the yield advantages (absolute as well as per cent) at various level were analyzed and their degree of variation was computed for all the crops across the seasons. The paper brings out the results of above analyses in objective manner.

Keywords: CFLD-Pulses, Sustainable Yield Index (SYI), Yield advantages

Pulses occupy a unique place in global agriculture due to their high protein content, which is nearly double that of cereals. India grows the largest varieties of pulses in the world and accounts for approximately 38% of the total area under pulse crops and 33% of the production, followed by other countries such as Canada, China, Myanmar, and Brazil. Pulses are often used as a meat substitute by the poor in India because they are the cheapest and richest source of many essential amino acids, and they meet the protein needs of a large vegetarian population. Pulse crops also enrich soil because they can fix atmospheric nitrogen in their roots and are thus a part of the nitrogen cycle. Major pulse-producing states in India are Madhya Pradesh, Maharashtra, Uttar Pradesh, Rajasthan, Andhra Pradesh, Karnataka, Gujarat, Chhattisgarh, and Bihar, which cultivate chickpea, pigeon pea, greengram, blackgram, lentil, and field pea. The area and production of pulses tend to fluctuate. Government of India launched Cluster Front Line Demonstrations (CFLDs) on Pulses, from the *rabi* season of 2015–16 as part of the food security mission and entrusted the responsibility to the Division of Agricultural Extension of the Indian Council of Agricultural Research (Singh 2016a, 2016b). The division enlisted 564 centres, the Krishi Vigyan Kendras (Hindi for agricultural science centres) across 24 states in the country forms the sources of data for the analysis.

The study sought to analyse the voluminous data emanating from these CFLDs in the pre-designed on-farm demonstrations of pulses varieties covering all the three cropping seasons in major pulse-growing states of India to showcase the production potential of pulses varieties in comparison with farmers' local checks. The investigations aimed to look at the yield of different pulses throughout seasons and harvests, the yield advantages gained due to CFLD, and the sustainable production level of different pulses.

MATERIALS AND METHODS

The present study is basically the analysis of large scale data generated through the CFLD on pulses across various major pulses growing states covered by the ICAR-

[1]ICAR-Agriculture Technology Application Research Institute, Kanpur, Uttar Pradesh; [2]ICAR, KAB-1, Pusa, New Delhi; [3]ICAR-ATARI, Jabalpur; [4]Ludhiana; [5]Shillong; [6]Jodhpur; [7]Kolkata; [8]Pune; [9]Guwahati; [10]Hyderabad; [11]Patna and [12]Karnataka.
*Corresponding author email: skumar710@gmail.com

ATARIs of Kanpur (Uttar Pradesh), Jodhpur (Rajasthan), Pune (Maharshtra), Jabalpur (Madhya Pradesh), Kolkata (West Bengal), Guwahati (Assam), Hyderabad (Andhra Pradesh), Bangaluru (Karnataka) and Patna (Bihar). The major pulse crops covered for the present analysis represent all three seasons namely *kharif* (pigeonpea, blackgram and greengram), *rabi* (chickpea, lentil and field pea) and summer (greengram) during 2016–17 and 2017–18. The demonstrations were laid out with improved varieties, viz. Asha, GT 103, LRG 52, Malviya 13, etc (pigeonpea); WB 109, Ujjawala, Uttara, PU 31, TBG 104, etc (blackgram); SML 668, IPM 2-3, WGG 42, HUM 16, etc (greengram); JG 14, JAKI 9218, GNG 1581, RSG 931, etc (chickpea); Rachna, Prakash, Pragati, IPFD 4-9, etc (field pea) and WBL 77, HUL 57, PL 08, etc (lentil). These improved varieties were complemented with technologies like raised bed planting, sprinkler irrigation, integrated pest management, integrated nutrient management, use of critical inputs, etc to have the essence of integrated crop management (ICM) approach in all the CFLDs conducted. The average performance data of CFLD were obtained for the above states for all the crops representing various growing seasons during the cropping seasons of 2016–17 and 2017–18. Thus, CFLD data were analyzed from across minimum of 21 states (greengram) and maximum of 24 states (blackgram). The major variables analyzed were average yield obtained from the check plots and demonstrations plots. These yields were computed for yield advantages and also compared with the reported district level, state level, national level yields and also the potential yields of the respective crops in the given states (procured from secondary sources for the year 2017–18). Accordingly, the yield advantages and sustainable yield index (SYI) was worked out for various pulses and across the season. The major variables taken for the study are defined as below alongwith their empirical measurements.

Yield advantage: Yield advantage was to the extent of gain in the reported yield of pulses at district level, state level and farmers' level as against the average yield obtained in the demonstrations.

$$\text{Yield advantage (\%)} = \sum_{i=1}^{n} (D_{yi} - R_{yi})_{D,S,D} / D_{yi}$$

where, D_{yi}, demonstration yield of ith farmer: R_{yi}, reported yield for the ith farmer against the district (D), state (S) and farmer (F) yield.

Sustainable Yield Index (SYI) was computed (Singh *et al.* 1990) to see the relative stability of the performance of various crops.

$$SYI = \frac{Y_t - \sigma}{Y_{max}}$$

where, SYI, Sustainable Yield Index; Y_t, Estimated average yield of a crop over years; σ, Estimated Standard deviation; Y_{max}, Observed maximum yield of the crop in that year.

The data were subjected to both descriptive and inferential statistics. The descriptive statistics utilized were average, percent and range. The inferential statistics were Coefficient of Variation (CV) to draw the meaningful implications. The analyzed data were presented in tabular as well graphical form.

RESULTS AND DISCUSSION

Pulses yield across the states and seasons: The cluster frontline demonstrations covered 31949 ha and 64 species and varieties of pulse crops over all the 3 seasons in the 2 years (Table 1). The table also gives the reported potential yield and the state- and national-level yields, the average yield from the demonstration plots, and that from the check plots. The highest yield (1.7 t/ha) from the treatment plots was recorded in field pea followed by chickpea (1.5 t/ha), the area under the two crops being 1890 ha and 8376 ha respectively. The maximum variation in yield (Fig 1) was seen in greengram grown in summer (CV = 34%) and the minimum, in blackgram (CV = 14%), mainly due to the much greater local and old varietal prominence in green gram. Large variation was also seen in the yield of chickpea from farmers' plots (CV = 30%) and that from the demonstration plots (CV = 32%), probably because of the low penetration of high-yielding chickpea varieties and improved technologies. In other words, the seed replacement rate was low in chickpea and greengram, farmers preferring to set aside from the current year's harvest the required quantity as seed for the next year. The greater variation in both the crops' yields across the states may also be due to the variation in management practices. On the other hand, the difference between yields from the demonstration plots and farmers' plots was much smaller (CV <20%) in field pea, *kharif* blackgram and pigeonpea (Fig 1). Results clearly indicated that blackgram, pigeonpea and field pea crops have established themselves with greater stability as compared to chickpea and summer greengram. Though the area (9.19 Mha) and production (8.22 million tonnes) of chickpea is highest among all pulses in India, the greater CV gives clue for more scope of harnessing the yield potential by evolving more situation specific varieties and packages of production practices. At the same time, the seed delivery system ought to be made effective by the main extension system of the country. The need to bring sufficient number of high yielding and disease resistant varieties in seed chain which should adequately represent all pulse growing areas in the country was emphasized long back by Reddy (2009) and reiterated even after many years by Chauhan *et al.* (2016). Therefore, aligning the pulses research agenda in the line with production situation characteristics is not ruled out. The need for participatory approach to plant breeding and variety selection has been also emphasized by Witcombe (1999) who highlighted how these approaches are being adopted in selection and breeding of better adapted varieties and because of the good results, these approaches are now spreading and many of the international agricultural research system has shown interest in this direction. Tian *et al.* (2021) while predicting if the potential yields are attainable and if yes, will it match the future food demand globally.

They analyzed that there shall be constant growth rate in food demand for the next three decades. Albeit, the crop production growth rate may gradually witness the declining trends and because of the very much likeliness of stagnant yield of major food crops in many of the European, American and Asian countries. Abeysiriwardena (2016) had already made an exhaustive review of the work on yield potential (Dawe and Dobermann 1998), potential yield (Reynolds *et al.* 2011) and maximum attainable yield (Evans 1993), and thus concluded that yield potential is not something for which the ideal climatic environment is the predictor and therefore, it may exhibit the regional and environment governed variation. Reynolds *et al.* (2011) used the term potential yield instead of yield potential and defined it as the maximum yield of a given species or cultivar possible achievable under existing conditions of solar radiation flux density with all the other environmental factors considered to be optimal. Thus, the potential yield is determined by the biological properties of the species or cultivar and radiation resources available for utilization.

Analysis of yield advantage: The CFLDs for pulse crops were created with the overarching goal of realizing the production potential of improved pulse varieties and better agricultural techniques. As a first step, it was necessary to determine the yield advantage – the difference between yields from farmers' fields and those from demonstration plots – for various crops, as well as to examine the differences between national and state average yields, check plot yields, and potential yields for the selected pulse crops. These data are presented in Table 2, whereas Fig. 2 shows the sustainable yield index, which is a measure of the deviation of average yield from the maximum yield reported for a given crop in a given year. It is evident from Table 2 that the improved varieties and better farming practices that were demonstrated on-farm

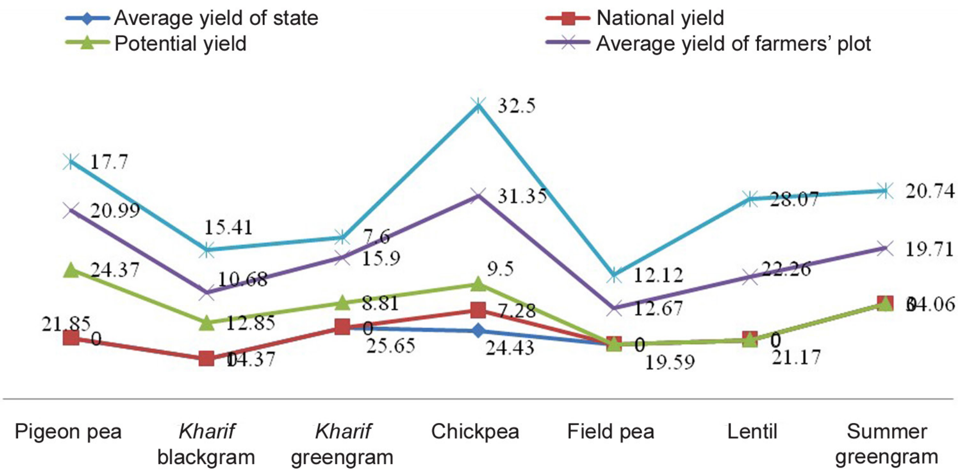

Fig 1 Coefficient of variation of state average yield, yield from check plots and from demonstration plots, and potential yield of pulse crops in India.

Table 1 Yield (tonnes/ha) of pulse crops across seasons and pulse-growing states in India

Crop	Data scale and range	Number of varieties	Area (ha)	Average reported yield (t/ha)				
				State average	National average	Potential yield	Check plots	Demo plots
Kharif (rainy) season								
Pigeonpea	19 states	9	5556	0.854 ± 0.19	0.78	1.9 ± 0.463	0.984 ± 1.99	1.42 ± 0.252
	Range			0.698–1.3		1.2.–2.4	0.690–1.25	1.79–1.12
Blackgram	24 states	11	6067	0.556 ± 0.08	0.627	1.07 ± 0.137	0.580 ± 0.06	0.851 ± 0.131
	Range			0.496–0.715		0.9–1.2	0.49–0.70	0.68–1.01
Greengram	23 states	6	2689	0.333 ± 0.09	0.515	1.066 ± 0.094	0.698 ± 0.111	0.934 ± 0.071
	Range			0.222–0.43		1.0–1.2	0.612–0.855	0.875–1.034
Rabi (winter) season								
Chickpea	21 states	19	8376	0.893 ± 0.218	0.907	2.063 ± 0.196	1.177 ± 0.3.69	1.554 ± 0.5.05
	Range			0.449–1.267		1.5–2.2	0.467–1.551	0.593–1.903
Field pea	17 states	2	1890	1.245 ± 0.2.44	0.941	2.500	1.255 ± 0.159	1.707 ± 0.207
	Range			1.000–1.490			1.096 -1.50	1.500–1.915
Lentil	19 states	7	3747	0.869 ± 0.188	0.700	2.150	0.867 ± 0.139	1.067 ± 0.372
	Range			0.600–1.105			0.623–1.125	0.837–1.875
Summer season								
Green gram	13 States	10	3624	0.458 ± 0.156	0.515	1.200	0.629 ± 0.124	0.945 ± 0.196
	Range			0.297–0.710			0.442–0.789	0.685–1.230

through the programme led to substantially higher yields, whether compared to the state average (yields in the demo plots were greater by 39.25–190.47%), to the national average (greater by 35.65–109.59%), or to the average yields obtained by farmers (greater by 31.63–51.36%). However, the yields even from the demonstration plots were much lower than the potential yields, as evident from the negative values of −38.83 to −15.04% for *rabi* pulses and, although to a lesser extent, for *kharif* pulses (20.36–23.04%). However, with respect to technology gap, extension gap and technology index of different cultivars of pigeonpea varied from 0.121 to 1.49 t/ha; 0.309 to 0.673 t/ha and 6.72 to 4%, respectively in Bihar and Jharkhand (Kumar *et al.* 2023). The overall demonstration yield varied between 1.04 to 1.78 t/ ha which is 22.55 to 71.68% more than the farmer's practices prevailing. These values of the yield advantage, especially when compared to potential yields, highlight the vast scope of improved varieties of pulses and improved methods of cultivating those varieties. Data (Table 2) also shows that although yields from the demonstration plots for *rabi* pulses (1.32–1.55 t/ha) were higher than those for *kharif* pulses (0.94–1.42 t/ha) and summer pulses (0.69–1.23 t/ha), yield advantages were in the reverse order – a pattern that indicates that yields from check plots of *rabi* pulses were higher than those of *kharif* pulses, an observation that also shows why the SYI of *kharif* and summer pulses was higher than that of *rabi* pulses (Fig 2). These findings suggest that, in order to increase yields, growers of *kharif* pulses should be encouraged to buy seeds of improved varieties from the specified sources or obtain them elsewhere, particularly from government agencies, KVKs, and state agricultural universities, rather than using the previous crop's produce as seed for the next crop. Another noteworthy finding evident from the data (Table 2) was the higher yield advantages of

Table 2 Increased yields (yield advantage) due to CFLD of pulse in India

Crop	Data scale and range	Yield from demonstration plots (t/ha)	Yield advantage of demonstration plots (t/ha)				Yield advantage of demonstration plots (%)			
			Over state-level yield	Over national-level yield	Over potential yield	Over yield from check plots	Over state-level yield	Over national-level yield	Over potential yield	Over yield from check plots
Kharif (rainy season)										
Pigeonpea	19 States	1.423 ± 0.252	0.569 ± 0.201	0.741 ± 0.253	−0.47 ± 0.99	0.47 ± 0.08	69.57	109.59	23.04	51.36
	Range	1.120–1.79	0.320–0.945	0.441–1.110	(−8.70)–(−0.6)	0.38–0.59				
Blackgram	24 States	0.850 ± 0.131	0.294 ± 0.111	0.223 ± 0.131	−0.216 ± 0.485	0.270 ± 0.093	54.18	35.65	21.57	46.62
	Range	0.683–1.012	0.158–0.512	0.056–0.385	(−0.52)–(0.08)	0.164–4.56				
Greengram	23 States	0.935 ± 0.05	0.591 ± 0.04	0.419 ± 0.05	−0.198 ± 0.303	0.236 ± 0.028	190.47	81.49	20.36	35.40
	Range	0.875–1.034	0.18–0.653	0.052–0.360	(−0.33)–(0.04)					
Rabi (winter season)										
Chickpea	21 States	1.554 ± 0.505	0.661 ± 0.529	0.6.47 ± 0.527	-0.510 ± 1.114	0.377 ± 0.176	83.17	73.57	−15.04	31.63
	Range	0.593–1.866	0.173–1.750	0.122–1.728	(−0.13)–(−0.18)	0.126–0.635				
Field pea	17 States	1.707 ± 0.207	0.462 ± 0.037	0.766 ± 0.207	-0.792 ± 1.598	0.452 ± 0.047	39.25	81.45	−31.70	36.10
	Range	1.5–1.92	0.425–0.500	0.559–9.74	(−0.10)–(−0.59)	0.404–0.50				
Lentil	19 States	1.325 ± 0.363	0.455 ± 0.278	0.625 ± 0.372	−0.825 ± 0.311	0.457 ± 0.193	52.23	89.25	−38.83	51.10
	Range	0.837–1.875	0.237–0.925	0.137–1.175	(−1.16)–(−0.33)	0.214–0.750				
Summer season										
Greengram	13 States	0.945 ± 0.196	0.486 ± 0.257	0.430 ± 0.195	−0.255 ± 0.546	0.316 ± 0.165	129.73	83.49	22.50	51.39
	Range	0.685–1.230	0.227–0.861	0.170–0.715	(−0.52)–(−0.32)	0.191–6.00				

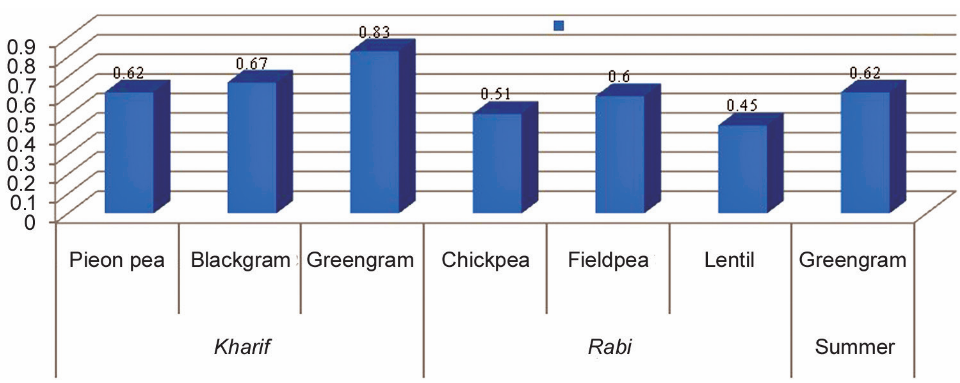

Fig 2 Sustainable yield index of demonstration plots of pulse crops in India.

the demonstration plots in all three *kharif* pulses and of summer greengram: the yield advantage was approximately 23% in the case of pigeonpea, 21.6% in that of blackgram, 20.4% in that of *kharif* greengram, and 22.5% in that of summer greengram, probably because both natural and technological resources were used more efficiently in *kharif* and summer seasons than in *rabi* season. However, yield analysis for CFLD-Pulses (lentil) revealed that average yield of the improved varieties (8.37 q/ha) was higher as compared to the farmers local variety (6.25 q/ha) with an incremental increase of 33.96%. The demonstration of improved varieties resulted in higher average net return by 84.25% as against the check variety. The overall B: C ratio was also observed to be higher in demonstrations (2.29) than the farmers' practice/check variety (1.78). Technology gap, extension gap, technology index and yield gap-II (%) were reported highest in the variety KLS-218 and lowest in the variety L-9 (Gogoi *et al.* 2019).

As discussed, the considerable yield advantages also helped to minimize the yield gap in pulses at various level (Dubey *et al.* 2022). The same researchers also established that yield gap minimized was more for *kharif* pulses like blackgram and also such gap being widest at the state-level (35.9–85.3%) and at the national level (35.9–79.3%) in all three seasons, it was bridged to maximum possible extent. Literature, however, further revealed that the researchers in past had main focus on quantifying the yield gaps in pulses. However, quantifying the yield gap minimization in pulses was reported maiden by Dubey *et al.* (2018). With references to paddy, the on-farm technology assessment minimized the extension gap to the extent of -0.59 to -1.21 kg/ha (Singh *et al.* 2020).

The coefficient of variation of yield was the highest for chickpea (31.35% for check plots and 32.5% for the demonstration plots) and the lowest for *kharif* blackgram for all the four categories, namely state average, yield of check plots and of demonstration plots and potential yield (Fig 2).

The greater variation in yield from the demonstration plots probably suggests that the improved varieties and the package of practices used on those plots do not 'translate' well across states. Similarly, the very small variation seen in *kharif* blackgram (CV: 14.37%) and *kharif* greengram (CV: 7.6%) indicates that the improved varieties and the package of practices for these two crops worked better than those for the *rabi* and summer pulses. The results (Fig 2) also show that *rabi* pulses had lower SYI (0.45–0.60) as compared to *kharif* (0.67–0.83) and summer (0.67) which indicates thereby that *rabi* pulses can be still exploited for their potential yield and there is greater scope for these crops specially lentil and chickpea whose per unit production can be enhanced for reaching the greater SYI level.

The scale at which these CFLDs are being carried out is adequate for determining the tangible impact. As a result, the average yield improvement is highly encouraging, surpassing even projected yields in several situations**.** Secondly, the cross sectional variation in the reported yield, and yield advantages across the states implicate for evolving the pulses varieties and technologies which are more unique to the given state or region. This is most likely the reason for the higher variability in the sustainable yield index (SYI). As a result, the pulses variety improvement initiative has a researchable agenda.

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