Article

Outlook on AGRICULTURE

Outlook on Agriculture
2017, Vol. 46(3) 230–235

DOI: 10.1177/0030727017726208
journals.sagepub.com/home/oag
SAGE

Assessing chickpea yield gaps in India: A tale of two decades

Avinash Kumar Srivastava[1], Girish Prasad Dixit[2] and Narendra Pratap Singh[1]

Abstract

Chickpea is a major pulse crop in India and critical in ensuring nutritional security to the largely vegetarian population of the country. Despite contributing more than 70% to the global chickpea area and production, India remains a net importer of chickpea due to high national demand. Although significant yield increases have been reported under experimental research conditions, farm-level increases have been more modest. The yield gaps between potential (research plot), achievable (frontline demonstration (FLD)) and farmer (national) have been estimated based on yield data from the Indian National Agriculture Research System trials and official data from the Ministry of Agriculture for the past 20 years. The potential yield showed a moderate increase while achievable yield showed slight negative growth. Over the same period, the average farmer yield reflected a slow but steady growth. This implies an opportunity to increase farmer yields through policy intervention and technology. Although the total yield gap between potential and that realized by farmers have remained the same over the years, yield losses have been due more to upscaling of technology than to variable fields managed by farmers. Farmers are realizing better yields which can be attributed to better access to improved varieties as well as favourable policy support. To obtain self-sufficiency in pulses by 2050, annual growth of 2.14% in production is required. This could be achieved through innovative research interventions backed up by appropriate policy support.

Keywords

Chickpea, yield, technology gap, self-sufficiency

Introduction

Pulses, commonly known as poor man's meat, play a vital role in providing the daily protein dietary requirement of a largely vegetarian population in the Indian subcontinent. Realizing the importance of pulses in human health, the General Assembly of the United Nations (UN) declared 2016 as International Year of Pulses (IYOP-2016). A UN dedicated year helped to raise awareness of pulses globally and the important role they can play in advancing health and nutrition, food security and environmental sustainability. This UN announcement came in the aftermath of back to back years of decreasing pulse production due to adverse weather conditions in India which accounted for the dominant share in global pulse production. Pulses in general have been neglected in India and are often termed orphan crops. The success of the Green Revolution in India was based on input intensive cultivation of cereals, mainly rice and wheat on the fertile soils of the Indo-gangetic plains; the area under other crops including pulses was either greatly reduced or shifted onto marginal land. This input-intensive technology further exacerbated the existing yield gap between major cereals and pulses. As a result, the relative profitability and competitiveness of pulse crops reduced even though prices increased due to shortage of supply to meet the rising demand. Another important reason for decreased preference of pulses by farmers was the continued higher instability in yields of pulse crops compared to major cereal crops (Chand, 2008). During 2015–2016, the total pulse production in India was around 16.35 million tonnes which required a record import of 5.79 million tonnes to meet consumer demand (Source: http://agricoop.nic.in/sites/default/files/Pulses.pdf). This shortfall could be met mainly through vertical expansion in yield of pulse crops and matching production and protection technologies.

Chickpea accounted for more than 43% (7.06 million tonnes) of the total pulse production (16.35 million tonnes) in India and about 85% of total pulse exports between 2015 and 2016 (DAC&FW, 2016). It is consumed in a myriad of ways including dal, wholegrain, flour and different preparation of snacks (Reddy, 2010), and its protein complements cereal-based diets with several essential amino acids.

[1] ICAR-Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, India
[2] AICRP on Chickpea, ICAR-Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, India

Corresponding author:
AK Srivastava, Crop Improvement Division, ICAR-Indian Institute of Pulses Research, Kalyanpur, Kanpur 208024, Uttar Pradesh, India.
Email: bhu.avinash@gmail.com

Chickpea cultivation is sustainable as it is typically grown in poor/marginal soils, with almost no additional fertilizer and insect pest control. It can also improve soil fertility and physical soil properties. The area under chickpea in India shows minor fluctuations depending on the rainfall pattern over the years but has seen a regional shift of about 4 million ha from the highly fertile North India to the relatively harsher environments in central and the southern India. Analysis of the potential for available technologies being developed at the experimental research field scale and the effects of upscaling to farmers will provide insights into the research and extension efforts required to increase national pulse production. Yield gap analysis has been utilized in different crops including cereals, pulses and oilseeds (Aggarwal et al., 2008; Mondal, 2011; Singh, 2012; Tavva et al., 2017) to assess the potential and adaptability of technology. In chickpea, many regional studies on yield gap have been conducted based on short-term data. These have reported yield gaps ranging from 21% to 54% in different states (Dwivedi et al., 2014; Kumar et al., 2014; Kumhare et al., 2014; Rajiv and Singh, 2014; Singh et al., 2013). Limited inference could be drawn from such studies as long-term data analysis to deduce trends have not been conducted. In this study, analysis has been made to differentiate yield gaps between potential, achievable and farmers' yields on the basis of data from two decades (1996–2015).

Methodology

The All India Coordinated Research Project on Chickpea (AICRPC) under the auspices of the India Council of Agricultural Research (ICAR), New Delhi, coordinates applied chickpea research in India. It tests improved technologies including chickpea genotypes, crop production and protection technologies and FLDs through a network of 25–30 centres which are strategically located across the country to represent specific agro-ecological regions. The yield levels obtained in such coordinated trials over a period of 20 years have been utilized for yield gap analysis. The maximum yield obtained in varietal evaluation trials under the AICRPC was considered to be the 'potential yield' of chickpea. The yields obtained under 'frontline demonstrations' on high-yielding varieties of chickpea were considered to be 'achievable yield', while national average yield of chickpea reported by the Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW), Ministry of Agriculture was considered to equate to 'farmer yield'. The period of study (1996–2015) was divided into four equal 5-year periods, namely 1995–2000, 2001–2005, 2006–2010 and 2011–2015. The mean values of chickpea yield were calculated for each duration. The coefficient of variation (CV) and compound annual growth rate (CAGR) was calculated for each 5-year period following standard methodologies. The yield gaps and their percentages were estimated utilizing the following formula (Samui et al., 2000):

$$\text{Yield Gap I (YG I)} = \text{Potential yield} - \text{Achievable yield}$$

$$\text{Yield Gap II (YG II)} = \text{Achievable yield} - \text{Farmer yield}$$

$$\text{Yield Gap I (\%)} = \frac{\text{YG I}}{(\text{YG I} + \text{YG II})} \times 100$$

$$\text{Yield Gap II (\%)} = \frac{\text{YG II}}{(\text{YG I} + \text{YG II})} \times 100$$

Results and discussion

The majority of chickpea is grown under rainfed conditions in India as it has a low requirement of fertilizers, irrigation and other agrochemicals and enriches the physical, chemical and biological environment of soil through biological nitrogen fixation (Jodha and Subba Rao, 1987). Conversely, cultivation on low-input traditional production systems has led to highly variable yields observed spatially over different locations as well as temporally through time. Studying such variations over an extended period helps to understand any underlying patterns in productivity as well as the yields realized by farmers. There has been a marked increase in the area under *rabi* (winter) pulses in India since 2000–2001 (Reddy et al., 2013) and currently more than two-thirds of total pulse production is from *rabi* (DAC&FW, 2016). Being major *rabi* crop, it therefore automatically demands increased attention since it plays a vital role in sustaining and increasing total pulse production in the country.

Linear trends in potential, achievable and farmer yield between 1995 and 2015

The potential yield realized in a crop reflects to some extent the strength of a country's breeding programme. In this study, the potential yield of chickpea showed a distinct increasing trend, rising from 1007 kg/ha in 1995–1996 to 1747 kg/ha in 2014–2015 (Figure 1). It then increased from 1864 kg/ha between 1996 and 2000 to 1951 kg/ha by 2001–2005, but then stagnated between 2006 and 2010 (Table 1). It increased again to 2022 kg/ha between 2010 and 2015. Overall the CAGR was 1.51% which is modest but still represents an increase in production potential for chickpea genotypes over the assessment period. Splitting the study into 5-year periods helps provide a picture of temporal changes in yield potential. The CAGR decreased from 16.05% in 1996–2000 to 10.74% in 2001–2005 and 4.91% in 2006–2010 and eventually became negative during 2011–2015 (−8.42%; Figure 2(a)). This indicates a need to inject changes in current breeding programmes to cope with problems of recent times possibly due to a changing climate as well as farmer preferences. It is important to remember that during each period, the maximum potential yield has increased but so did the CV which indicates the crop is increasingly being affected by external factors thus making it more vulnerable. Singh et al. (2009) observed large variations (1250–2200 kg/ha) in potential rainfed chickpea yield based on simulated and experimental station data. Thus, we need to assess and set a realistic target for yield improvement, bearing in mind the increasing stress

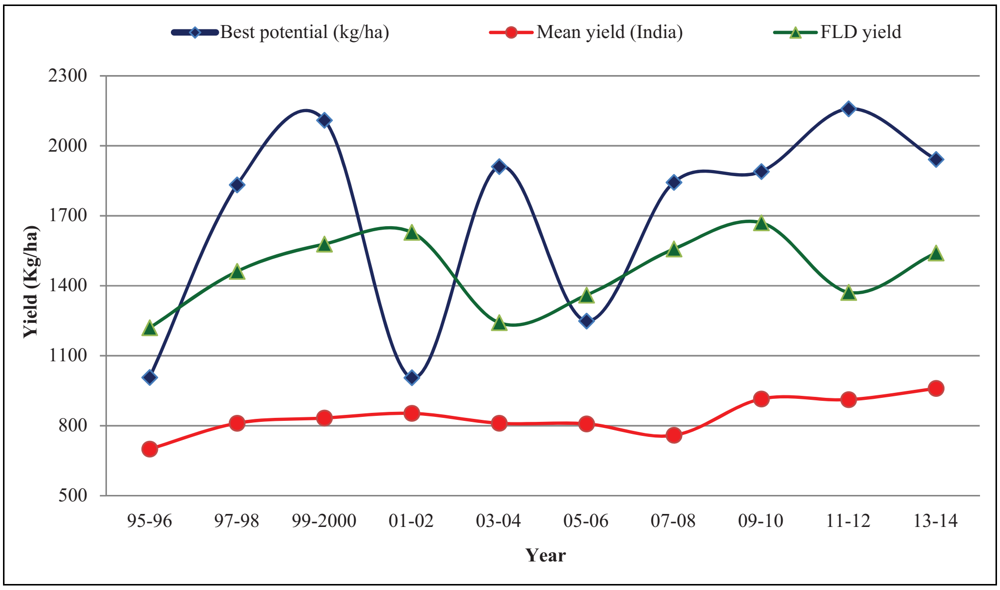

Figure 1. Trend in potential, achievable and farmer yield between 1996 and 2015.

Table 1. Five yearly mean of potential, achievable and farmer yield of chickpea (1996–2015).[a]

	Potential yield (kg/ha)				Achievable yield (kg/ha)				Farmers yield (kg/ha)			
Duration	Mean	Range	CV (%)	CAGR (%)	Mean (No.)	Range	CV (%)	CAGR (%)	Mean	Range	CV (%)	CAGR (%)
1996–2000	1864	1690–2110	8.16	16.05	1481 (1177)	1220–1640	10.88	4.37	792	700–833	6.64	3.41
2001–2005	1951	1709–2294	12.80	10.74	1502 (1023)	1242–1765	15.50	−8.86	788	717–853	7.08	1.33
2006–2010	1959	1703–2415	13.79	4.91	1500 (2913)	1360–1670	7.90	4.41	841	759–915	7.59	3.30
2011–2015	2022	1690–2572	17.72	−8.42	1459 (971)	1321–1601	9.15	−1.64	924	895–960	3.00	2.04

CAGR: compound annual growth rate; CV: coefficient of variation; FLD: frontline demonstration.
[a]Figures in parentheses indicate number of FLDs conducted.

due to various biotic and abiotic factors as well as changing farmer traits for factors such as seed size.

The achievable yield, as reflected by the average yield in FLDs, followed similar pattern to potential yield. It increased from 1481 kg/ha during 1996–2000 to 1500 kg/ha during 2001–2005 and remained at same level for the next 5 years. Between 2011 and 2015, it declined further to 1459 kg/ha, the lowest average FLD yield recorded in 20 years. This decrease in recent years could be attributed to adverse weather in 2014 and 2015 (Bhat, 2014; ICAR, 2015). The CAGR also fluctuated between periods. It showed a +4.6% growth between 1996 and 2000 before dropping to −8.86% between 2001 and 2005 (Figure 2(b)). Overall, a CAGR of −0.05% was observed indicating a slight decrease in FLD performance. Although the CV was higher during the initial decade, it remained below 10% in the following decade, possibly signifying an improvement in the conduct of FLDs in recent years.

The average farmer yield has shown a gradual increase from 700 kg/ha to 960 kg/ha over the 20 years. It remained below 800 kg/ha from 1996 to 2005 but then increased steadily to 841 kg/ha and 924 kg/ha during 2005–2010 and 2011–2015, respectively. The CAGR has remained positive throughout the period at +1.21% (Figure 2(c)). Due to a gradual increase in yield over the period, the CV remained low for the duration. Thus, a slow but steady increase has been observed in chickpea yield at the farmer level which implies that with the right kind of technology and policy support, there could be further increases in yield without a significant increase in terms of the cultivated area under pulses.

Yield gap analysis

The potential yield obtained at a research station is usually achieved under very carefully managed conditions in small plots, conditions which are is not directly replicable in a farmer's field. Yield gap I (YG I) represents the proportion of potential yield that is lost in upscaling from the demonstration plot and is termed the 'technology' gap. YG I is present at all the times, and the only way to minimize it is to continuously increase the potential yield while keeping YG I to a manageable proportion (25–30%). The YG I as a proportion of potential yield increased with each period from 20.5% in 1996–2000 to 27.8% between 2011 and 2015. This was mainly due to the higher rate of increase in potential yield with a moderate rate of increase in achievable yield. Reddy et al. (2007) reported that YG I was highest in the south zone (30%) and lowest (17%) in the northwest zone of India. The area under chickpea in the

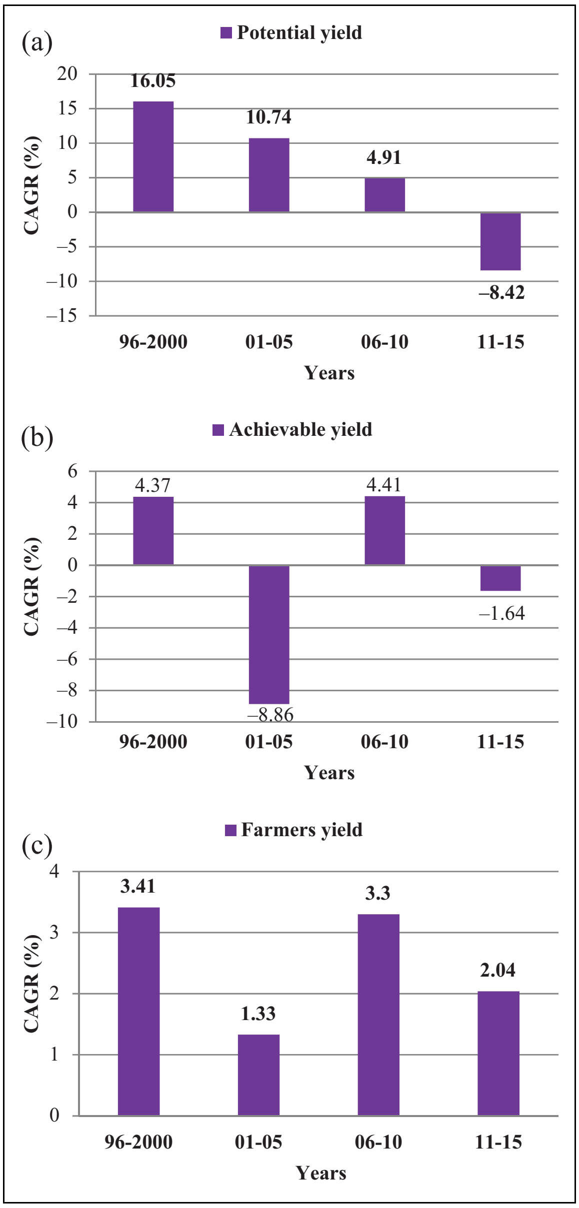

Figure 2. CAGR for potential yield (a), achievable yield (b) and farmer yield (c) between 1996 and 2015. CAGR: compound annual growth rate.

south zone has increased in recent years mainly due to the development of short-duration and wilt-resistant chickpea varieties including JG 11, KAK 2, JAKI 9218 and Vihar which are better adapted to short season, warmer environments in southern India and a high adoption of improved cultivars and production technologies (Gaur et al., 2008; Gowda and Gaur, 2004). Nevertheless, the average productivity is still low in the region which needs to be addressed. The northwest zone is the traditional chickpea growing belt with a number of varieties suitable for cultivation and hence with a low YG I. The CV also increased from 33.5% in 1996–2000 to 54.3% between 2001 and 2005. The CV remained above 70% during 2006–2010 and 2011–2015. This indicates an increased fluctuation in both the potential and achievable yield over the period (Table 2) suggesting a need for development of more climate resilient chickpea varieties.

Yield gap II (YG II) is the gap between achievable yield under standard management practices and the actual yield obtained under farmer managed conditions and is termed the ‘extension’ gap. The YG II increased between 2001 and 2005 (714 kg/ha) compared to 1996–2000 (689 kg/ha) but has since reduced. Based on modelling, Bhatia et al., (2006) reported that the YG II formed a significant part of the total yield gap in soyabean, groundnut, pigeonpea and chickpea in India. The YG II as a proportion of achievable yield slightly increased from 46.5% in 1996–2000 to 47.5% between 2001 and 2005. It then declined to 43.9% (2006–2010) and 35.9% between 2011 and 2015. This is mainly due to a relatively constant achievable yield and slow but steady increase in farmer yield over the period. Reddy et al. (2007) reported a large YG II ranging from 64% in the north zone to 148% in the central zone of India. Such large variations offer scope for increasing farmer yield through adoption of recommended best practices. This study indicates that the YG II has decreased over the period possibly due to concerted efforts in demonstrating the potential from improved technology leading to realization of better farmer yields in recent times. The CV ranged from 16.6% between 1996 and 2000 to 36.7% in 2001 and 2005, but remained below 25% for most of the period indicating less variation in YG II. The high variation in YG II across different locations indicated varying levels of adoption of technology and improved cultural practices among farmers at these locations (Bhatia et al., 2006).

A proportion of improved farmer yields could be attributed to favourable policy support by the Government since the beginning of the twenty-first century. For example, the National Food Security Mission (NFSM)-Pulses is an ongoing program to increase pulse production and covers 16 major pulse producing states accounting for c97.5% of the total pulse cropped area in the country. The Accelerated Pulses Production Program (A3P) was launched in 2010 as a part of the NFSM-Pulses for demonstration of production and protection technologies in village-level blocks. The Rashtriya Krishi Vikas Yojana (RKVY) program and Macro Management of Agriculture Scheme also provide support to farmers in integrated development in nearly 60,000 pulses and oilseeds villages (Rimal et al., 2015).

The total yield gap provides an estimate of potential yield loss from research station to a farmer field. Over the period, it is within the range of 1000–1200 kg/ha. With an average productivity of 960 kg/ha, it is evident that more than that is lost during the transfer of technology from research to farm. The total yield gap as a proportion of potential yield has remained between 50% and 60% over years. It has fluctuated around 55 to nearly 60% over the reporting period. Although the total yield gap has reduced in recent years, farmers are still realizing less than 50% of potential yield. The CV has also increased from nearly 10% in 1996–2000 to c35% between 2011 and 15. This highlights the importance of recognizing various biotic and abiotic stresses and need for research to include increased climate resilience as a breeding goal. Analysis indicates that the YG I has been increasing over the years with a subsequent decrease in YG II resulting in a nearly constant

Table 2. Yield gap analysis for chickpea yield between 1996 and 2015.[a]

	Yield gap I (kg/ha)			Yield gap II (kg/ha)			Total yield gap (kg/ha)		
Year	Mean	Range	CV (%)	Mean	Range	CV (%)	Mean	Range	CV (%)
1996–2000	383 (20.5)	195–531	33.53	689 (46.5)	520–827	16.62	1072 (57.5)	990–1277	10.86
2001–2005	448 (23.0)	104–689	54.29	714 (47.5)	431–1021	36.70	1163 (59.6)	880–1577	26.07
2006–2010	459 (23.4)	220–974	70.56	659 (43.9)	552–799	16.88	1118 (57.1)	808–1585	25.94
2011–2015	563 (27.8)	89–1113	70.05	524 (35.9)	341–672	24.22	1087 (53.8)	761–1677	35.44

CV: coefficient of variation.
[a]Figures in parentheses indicate yield gap in percentage.

level of total yield gap at national level. This implies that the FLDs on high-yielding varieties has been successful in helping to increase farm-level yields, but much still needs to be done. There has been an increase of c200 kg/ha in national average yield from 1996 to 2015. Between 2001 and 2015, the average yield gap II was 524 kg/ha. Even realization of 50% of this yield gap would lead to a significant increase in yield for chickpea in the country. Such a yield gap also provides considerable scope to improve the productivity chickpea through timely research and policy interventions. Various studies have reported that specific interventions could have major implications in enhancing system productivity (Katare et al., 2011; Mitra and Samajdar, 2010; Mukharjee, 2003).

In order to achieve self-sufficiency, the pulse requirement in India is projected to be 39 million tonnes by 2050 which necessitates an annual growth rate of 2.14% (IIPR, 2011). The yield gap could be bridged by bringing additional cultivated area under pulses and increasing productivity. The possibility of expansion of chickpea into nontraditional areas such as rainfed rice and fallow lands has been advocated (Joshi et al., 2005; NFSM, 2012), and large-scale on-farm trials conducted by several State Agriculture Universities in Chhattisgarh, Jharkhand, Orissa, West Bengal and eastern Madhya Pradesh have clearly demonstrated suitability of short-duration varieties of chickpea as an additional crop in rice fallows (Gowda et al., 2013). However, these areas are characterized by water stress, soil salinity in the case of rainfed rice fallows, low market linkages and credit availability (Inbasekar, 2014) which need to be addressed to bring these areas under pulse cultivation. Srivastava et al. (2010) also emphasized the hidden potential of some minor states in increasing pulse production for long-term sustainability.

Although the minimum support price (MSP) among all pulses has shown a positive increasing trend in recent years, it has failed to evoke a proportionate response from farmers regarding areal expansion and production. The price of pulses in most years have been more than the MSP indicating that more focus should be given to further reducing the costs of production. Reddy and Mishra (2009) reported that the production response to price in pulses, in general, is rather weak and nonprice factors such as high-yielding/modern varieties, technology and better infrastructure including adequate procurement systems are more important for accelerating pulse production. Recently, the Government launched "Pradhan Mantri Krishi Sinchai Yojana" and "Pradhan Mantri Fasal Bima Yojana" schemes which not only provide a more efficient insurance support to farmers but also much needed support for micro-irrigation system investment through a "Per Drop More Crop" campaign which can immensely beneficial for rainfed crops such as pulses. In promoting pulse cultivation, the Government has made provision of Rs 500 crores to strengthen and enhance breeding (ICAR and National Agriculture Research and Education System) and quality seed production with a provision to establish 150 seed hubs and large-scale demonstrations through *Krishi Vigyan Kendras* (KVKs)/on-farm centres. With the availability of technologies including high-yielding varieties developed by ICAR and NARES and devising and implementation of appropriate policies such as ensured supply of quality seed and other farm inputs, remunerative MSP, procurement and investment in the creation of infrastructure for seed/grain stocks, an additional 4–5 million tonnes of pulses could be produced in the short term (Chaturvedi and Sandhu, 2016).

Conclusion

Chickpea yield in India has shown a steady increase over years but a large proportion of potential yield is still lost in the translation from research to farm level. Some of these losses are inevitable due to differences in management practices at research stations and farm fields. However, a large fraction could be recovered be adopting good agricultural practices and improvement in institutional, infrastructure and policy support to farmers. This study provides a detailed analysis of yield gaps in chickpea over a 20-year period and provides insights to the problems and solutions regarding chickpea cultivation and expansion. Many steps have been taken recently to incentivise cultivation in India including timely availability of inputs, crop insurance, micro-irrigation facilities, remunerative MSP, systematic procurement and creation of infrastructure for seed/grain buffering which will be critical in increasing yield and providing long-term stability to pulse production in India.

Declaration of conflicting interests

The author(s) declared no potential conflict of interest with respect to the research, authorship and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship and/or publication of this article.

References

Aggarwal PK, Hebbar KB, Venugopalan MV, et al. (2008) *Quantification of yield gaps in rainfed rice, wheat, cotton and mustard in India. ICRISAT. Global theme on Agro-ecosystems report* # 43. Patancheru, Andhra Pradesh, India: Monograph. International Crops Research Institute for the Semi-Arid Tropics.

Bhat S (2014) Impact of untimely rains and hailstorms on prices of chickpea. *Pulses Newsletter Indian Institute of Pulses Research* 25(1): 6.

Bhatia VS, Singh P, Wani SP, et al. (2006) *Yield Gap Analysis of Soybean. Global Theme on Agroecosystems Report no. 31*. International Crops Research Institute for the Semi-Arid Tropics India.

Chand R (2008) The global food crisis: causes, severity and outlook. *Economic and Political Weekly* 43(26): 137–144.

Chaturvedi SK and Sandhu JS (2016) Strategies to increase productivity of pulses in India. *In Pulse Handbook* 6: 84–92.

DAC&FW (2016) 3rd advance estimate of production of foodgrain for 2015–16. Directorate of economics and statistics, GOI. Available at: http://eands.dacnet.nic.in/Advance_Estimates.htm (accessed 10 July 2016).

Dwivedi AP, Mishra A, Singh SK, et al. (2014) Yield gap analysis of chickpea through front line demonstration in different agroclimatic zones of M.P. and Chhatishgarh. *Journal of Food Legumes* 27(1): 60–63.

Gaur PM, Kumar J, Gowda CLL, et al. (2008) Breeding chickpea for early phenology: perspectives, progress and prospects. In: Kharkwal MC (ed) *Food Legumes for Nutritional Security and Sustainable Agriculture*, New Delhi, India, pp. 39–48.

Gowda CLL and Gaur PM (2004) Global scenario of chickpea research present status and future thrusts. In: Ali M, Singh BB, Kumar S and Dhar V (eds) *Pulses in New Perspective*, Indian Society of Pulses Research and Development, IIPR, Kanpur, India, pp. 1–22.

Gowda CLL, Srinivasan S, Gaur PM, et al. (2013) Enhancing the productivity and production of pulses in India. In: *Sustainable Food Security*, National Institute of Advanced Studies, Bangalore and Indian Council of Agricultural Research, New Delhi, pp. 145–159.

ICAR (2015) Unseasonal rains during 1st week of March 2015 - Contingency Recommendations. Available at: http://www.icar.org.in/files/Contingency-Unseasonal-Rainfall-2015.pdf.

IIPR—Indian Institute of Pulses Research (2011) Vision 2050. Kanpur. Available at: www.iipr.res.in/pdf/vision_250715.pdf (accessed 10 July 2016).

Inbasekar K (2014) Pulses production in India: challenges and strategies. *Economic Affairs* 59(3): 403–414.

Jodha NS and Subba Rao KV (1987) Chickpea: world importance and distribution. In: Saxena MC and Singh KB (eds) *The Chickpea*, CAB International, Wallingford, UK, pp. 1–10.

Joshi PK, Asokan M and Bantilan MCS (2005) Chickpea in nontraditional area: evidence from Andhra Pradesh. In: *Impact of Agricultural Research: Post-Green Revolution Evidence from India*, International Crops Research Institute for the Semi-Arid Tropics, India, pp. 115–129.

Katare S, Pandey SK and Mustafa M (2011) Yield gap analysis of rapeseed-mustard through front line demonstration. *Agric Update* 6: 5–7.

Kumar S, Singh R and Singh S (2014) Assessment of gaps in pulse production in Hamirpur district of Himachal Pradesh. *Indian Research Journal of Extension Education* 14(2): 20–24.

Kumbhare NV, Dubey SK, Nain MS, et al. (2014) Micro analysis of yield gap and profitability in pulses and cereals. *Legume Research* 37(5): 532–536.

Mitra B and Samajdar T (2010) Yield gap analysis of rapeseed-mustard through front line demonstration. *Agricultural Extension Review* 22: 16–17.

Mondal HM (2011) Causes of yield gaps and strategies for minimizing the gaps in different crops of Bangladesh. *Bangladesh Journal of Agricultural Research* 36(3): 469–476.

Mukharjee N (2003) *Participatory Learning and Action*. New Delhi: Concept Publishing Company, pp. 63–65.

NFSM (2012) NFSM-Progress Report No: 5, (2011–12). Enhancing chickpea production in Rainfed Rice Fallow Lands (RRFL) of Chhattisgarh (CG) and Madhya Pradesh (MP) states of India following Improved Pulse Production and Protection Technologies (IPPPT).

Rajiv and Singh L (2014) Performance of pulses demonstrations in Bundelkhand zone of Uttar Pradesh, India. *Indian Journal of Applied Research* 4(3): 1–3.

Reddy AA and Mishra D (2009) Growth and instability in chickpea production in India: a state level analysis. Available at: http://ssrn.com/abstract=1499577 (accessed 10 July 2016).

Reddy AA, Bantilan MCS and Mohan G (2013) *Pulses Production Scenario: Policy and Technological options, Policy Brief 26*. Telangana: International crop Research Institute for the Semi-Arid Tropics.

Reddy AA, Mature VC, Yadav M, et al. (2007) Profitability in chickpea cultivation. In: Yadav SS, Redden B, Chen W and Sharma B (eds) *The Chickpea Breeding and Management*, Wallingford, Oxon: CAB International, pp. 292–321.

Reddy AA (2010) Regional disparities in food habits and nutritional intake in Andhra Pradesh, India. *Regional and Sectoral Economic Studies* 10: 2.

Rimal NS, Kumar S, Singh DR, et al. (2015) Sources of growth in pulses production in India. *Agricultural Economics Research Review* 28(1): 91–102.

Samui SK, Maitra S, Roy DK, et al. (2000) Evaluation on frontline demonstration on groundnut. *Journal of Indian Society of Coastal Agricultural Research* 18(2): 180–183.

Singh J, Gautam US, Singh AK, et al. (2013) Yield gap analysis of gram through front line demonstration. *Asian Journal of Soil Science* 8(2): 518–519.

Singh M (2012) Yield gap analysis in rice, wheat and pulses in India. *Annals Agricultural Research New Series* 33(4): 247–254.

Singh P, Aggarwal PK, Bhatia VS, et al. (2009) Yield gap analysis: modelling of achievable yields at farm level'. In: Wani SP, Rockström J and Oweis T (eds) *Rainfed Agriculture: Unlocking the Potential*. Wallingford, Oxfordshire, UK: CAB International, Nosworthy Way, pp. 81–123.

Srivastava SK, Sivaramane N and Mathur VC (2010) Diagnosis of pulses performance of India. *Agricultural Economics Research Review* 23: 137–148.

Tavva S, Aw-Hassan A, Rizvi J, et al. (2017) Technical efficiency of wheat farmers and options for minimizing yield gaps in Afghanistan. *Outlook on Agriculture* 46(1): 13–19.