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Studies on Intervention of Improved Technology for Reducing Yield Gap and Improving Productivity of Chickpea in Eastern-Gangetic Plains of India

A.K. Mauriya[1], Vinod Kumar[1], R.B. Verma[2], Pankaj Kumar[3], Anita Kumari[3], Mamta Kumari[3], R.K. Verma[4]

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ABSTRACT

Background: Cluster front line demonstration is the unique approaches to increase pulse production through the horizontal dissemination of newly release latest improved production techniques (like seed treatment, improved varieties, timely sowing in residual moisture, insect pest, diseases and weeds control *etc*.) under the direct supervision of scientists.

Methods: The current study was conducted in the field of 390 farmers who were chosen for the study in *Rabi* season of 2016 - 17 to 2022-2023. Twenty six villages included 8 blocks including Goradih, Kahalgaon, Nathnagar, Pirpainti, Sabour, Sanhaula, Shahkund and Sultanganj in Bhagalpur district. These villages are classified as being in the South-Western Alluvial plain zone (zone IIIB) of Bihar. In 130 ha of land under the rainfed and irrigated agricultural condition, a total of 325 field demonstrations on chickpea were conducted. The soil type ranged from silty loam to clay loam with average value of OC 0.41%, pH 7.23, EC 0.28 dS/m and available N, P_2O_5 and K_2O 168.7, 21.36 and 218.53 kg/ha, respectively. The upgraded technology consisting of use of improved varieties (GNG-1581, PG-186, GCP-105 and RVG 202), recommended seed rate, seed treatment, line sowing, timely sowing in residual moisture, soil test based fertilization, management of weed, insect, pest and diseases under cluster front line demonstrations (CFLDs).

Result: Average performance of seven years observations indicated that the adoption of CFLD recorded higher yield (13.87 q/ha) and surpassed the existing farmer's practice (10.15 q/ha) by the margin of 36.73%. Surplus cost of Rs. 2977/ha under CFLDs resulted in surplus return of Rs. 20353 /ha and surplus gain Rs. 17376 /ha in chickpea. The B: C ratio in CFLDs also ranged from 2.43 to 3.20 with an average of 2.85 as compared to farmer's practice 2.34. The progressive increase in yield and economics of chickpea under CFLD was mainly due to the gap of technology, extension and Index of technological, which were respectively 7.13 and 3.72 q/ha and 33.82 per cent.

Key words: Chickpea, Economics, Extension gap, Technology gap, Technology index, Yield.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is one of the major *Rabi* pulse crops grown predominantly in northern India. India ranks first in pulse production (27.70 mt) with an area of 3.10 m ha and productivity of 892 kg/ha (DES, 2021). India is the largest producer and consumer of chickpea in the world with an area, production and productivity of 10.17 m ha, 11.35 mt and 11.16 q/ha, respectively (DES, 2021), however, in Bihar, chickpea is grown in an area of 0.051 m ha with total production of 0.054 m tonnes and productivity of 10.53 q/ha (DES, 2022) with the highest production share of 45.53 per cent in country followed by pigeon pea (17.06 per cent), urdbean (13.40 per cent), mungbean (7.76 per cent), lentil (5 per cent) and field pea (5 per cent). Chickpea is a rich source of protein (24%), carbohydrates (59.6) and minerals (3.2%) and plays an important role in vegetarian human diet as well as its straw as animal feed (Singh *et al.,* 2015), which improve animals health and milk production. The per-capita availability of pulses had decreased gradually from 80 g to 42 g per capita/day (WHO) due to the higher growth rate of the population and low growth rate of production and productivity of pulses. Besides, the traditional methods of cultivation like use of old varieties with poor quality seed, no use of external inputs (fertilizer, weedicide and pesticide), broadcasting sowing with higher seed rate and biotic/abiotic stresses could be the major reasons for low productivity, that emphases the

[1]Krishi Vigyan Kendra, (Bihar Agricultural University, Sabour, Bhagalpur), Araria-854 312, Bihar, India.
[2]Department of Horticulture (Veg. and Flori.), Bihar Agricultural University Sabour, Bhagalpur-813 210, Bihar, India.
[3]Krishi Vigyan Kendra, (Bihar Agricultural University, Sabour, Bhagalpur), Bhagalpur-812 001, Bihar, India.
[4]Krishi Vigyan Kendra, (Bihar Agricultural University, Sabour, Bhagalpur), Madhepura-852 113, Bhagalpur, Bihar, India.

Corresponding Author: A.K. Mauriya, Krishi Vigyan Kendra, (Bihar Agricultural University, Sabour, Bhagalpur), Araria-854 312, Bihar, India. Email: ak.mauriya12@gmail.com

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need to create awareness among the farming community to popularize the location specific improved varieties, improved technologies and package of practices to increase the production and productivity of pulse crops.

In recent years, the production and productivity of chickpea has increased due to inclusion of high yielding varieties, seed treatment, line sowing, integrated pest and weed management have potential to improve productivity of chickpea (Dhillon *et al*., 2021). The productivity was further increased by adopting better crop management practices (Kumar, 2014). This indicates that the low yield of chickpea in farmers' fields is mainly due to large gaps between farmers' practices recommended improved technology. The technological gaps may be in soil fertility status and weather condition. For minimizing these gaps, the Indian Council of Agricultural Research (ICAR), New Delhi introduced cluster frontline demonstrations (CFLDs) in the year 2015 under National Food Security Mission for promotion of pulses. The main objective of CFLDs programme is to demonstrate the latest crop production and protection technologies at farmers' field under close supervision of KVKs scientists to minimize the adoption gap. Keeping these problems under consideration, a study was conducted to improve the productivity of the chickpea by determining the yield gaps, technological gap, extension gap, technology index, technology adoption and horizontal spread at farmer's fields in participatory mode in different selected villages of Bhagalpur district.

MATERIALS AND METHODS

The investigation entitled 'Studies on intervention of improved technology for reducing yield gap and improving productivity of chickpea in Eastern-Gangetic Plains of India' a cluster front line demonstrations (CFLDs) was conducted by Krishi Vigyan Kendra Sabour, Bhagalpur during *Rabi* season from 2016-17 to 2022-2023 (7 consecutive years) in 26 villages of 8 blocks *viz.,* Goradih, Kahalgaon, Nathnagar, Pirpainti, Sabour, Sanhaula, Shahkund and Sultanganj under Bhagalpur district that are categorized under South-Western Allu*via*l plain zone (zone IIIB) as per the agro climatic Zones of Bihar (Table 1). Before conducting CFLDs, a group meeting and specific training was organized at village wise and only interested farmers were purposely selected for cluster front line demonstrations. Large, medium and small holding size farmers were included in the study. Co-operative farmers group were identified based on their participation and feedback received during the preliminary survey and interactive meeting for data and opinion collections related

Table 1: Geo map of CFLDs conducted location/site during 2016-17 to 2022-23.

Year	Village	Block	Latitude	Longitude
2016-17	Phulwariya	Sanhaula	25°09.007′	086°47.954′
	Arar	Sanhaula	25°07.402′	086°15.142′
	Ganga Prasad	Nathnagar	25°12.478′	086°54.218′
	Bhattha Chak	Shahkund	25°09.013′	086°47.973′
	Basantpur	Sultanganj	25°13.817′	086°50.354′
	Shobhnathpur	Kahalgaon	25°13.428′	087°16.895′
	Kalyanpur Bhuska	Kahalgaon	25°13.467′	087°16.810′
	Akabarpur	Kahalgaon	25°14.633′	087°19.221′
	Kharwa	Goradih	25°09.434′	087°05.845′
	Badalu Chak	Goradih	25°07.569′	087°01.632′
	Barhari	Goradih	25°07.754′	087°02.194′
2017-18	Tarar	Sanhaula	25°11.186′	087°10.098′
	Mirhatti	Sultanganj	25°06.462′	087°05.539′
	Tarchha	Goradih	25°06.478′	087°05.541′
	Ramchandrapur	Goradih	25°07.506′	087°03.900′
	Harla	Pirpainti	25°13.355′	087°28.042′
	Marchirma	Shahkund	25°07.381′	087°55.149′
2018-19	Kanjhiya	Nath Nagar	25°13.663′	086°55.017′
	Belsira	Nathnagar	25°19.554′	086°29.027′
	Harla	Pirpainti	25°21.253′	087°45.525′
2019-20	Kathara	Sultanganj	25°20.713′	086°73.742′
	Chaurchak	Sultanganj	25°20.689′	086°73.395′
2020-21	Ganga Kahariya	Goradih	25°09.594	087°12.160′
2021-22	Tamauni	Nathnagar	25°17.3476	086°93.0861′
2022-23	Rajpur	Sabour	25°21.7947	078°07.0147′
	Maniyarpur	Nathnagar	25°19.1319	086°89.1955′
	Fattachak	Nathnagar	25°16.8978	086°92.8465′

to demonstration of improved technology. The total sum of 325 CFLD in 130 ha area under both irrigated and rainfed farming situation by the active participation of 390 farmers were conducted during seven years with involvements of improved and existing farmers' practices. Almost the soil of the CFLDs sites was silty loam to clay loam in texture, with an average of soil pH 7.23, EC 0.28 dS/m, organic carbon 0.41%, available N 168.7 kg/ha, P_2O_5 21.36 kg/ha and K_2O 218.53 kg/ha. The meteorological data on rainfall and temperature (Min, Max) is presented in Fig 1. The major gaps between improved technologies and farmers' practices of chickpea for low yield were identified through PRA/preliminary discussion with selected farmers and prioritized as give in Table 2.

CFLDs was conducted on the basis of identified causes for low yield in integrated crop management manner as suggested by Choudhary (1999) and Venkattakumar *et al.* (2010). In control plots the existing farmer's practices were followed. The significant technological critical inputs like seed of improved varieties (GNG-1581, PG-186, GCP-105 and RVG 202), *Trichoderma viride*, Chloropyriphos, *Rhizobium* and PSB culture for seed treatment, sex pheromone trap for control of r pod borer were given to selected farmers from the Krishi Vigyan Kendra, Bhagalpur under CFLDs and remaining technological critical inputs were arranged themselves by the farmers. The details of CFLDs are given in Table 3.

All the technological interventions were taken as per prescribed package and practices for improved variety of chickpea. Before conducting CFLDs, specific skill trainings were organized with involving the selected farmers and local extension functionaries in their villages/KVK center regarding various aspects of improved technologies of chickpea production. In case of farmers practice(control plot), the traditional practices were followed by using existing varieties (known as desila in local name) with high seed rate (125-140 kg/ha), without *Rhizobium* inoculation, imbalanced use of fertilizer, no proper management of weed, pod borer (*Helicoverpa armigera*) and wilt. Subsequently demonstrated crops were visited during different crop growth stages by the KVK scientists to ensure proper guidance to the farmers. Different group meeting, field visit and training programme were organised at various stages of crop to aware non-beneficiaries and beneficiaries farmers and extension personnel to witness the benefits of demonstrated technology. Finally field day was organised at demonstrated plot with involving selected farmers, other farmers of the villages and local extension functionaries to show the superiority of the technology and disseminate to message in large scale. The crops were harvested in third week of March to first week of April after maturity.

The yield data were collected from both the demonstration and existing farmers practice (control plot)

Table 2: Differences between improved technologies under CFLD and farmers' practices.

Particular	Application improved technologies	Farmer's practice	Gap
Variety	Latest improved varieties (given in table as per year wise)	Desila (old and degenerated)	Full gap
Seed treatment	Seed treatment with *Trichoderma viride* @ 5.0 ml or g/kg seed, Chloropyriphos 20% EC @8.0 ml/kg seed, *Rhizobium* culture @ 20 g or 5 ml/kg seed, PSB culture @ 20 g or 5 ml/kg seed	Without seed treatment	Full gap
Land preparation	Three ploughing	Three ploughing	Nill
Sowing time	15th October to 20th November	Second week of November to end of November, Sometime in first week of December	Partial gap
Sowing in residual moisture	Yes	Yes/no	Partial gap
Seed rate	75 kg/ha on the basis of seed size (small seeded)	125-140 kg/ha	Higher seed rate
Fertilizer dose	Balance dose of fertilizers in INM manner	imbalance/No. use of fertilizer	Full gap
Weed control	Pendimethalin @ 1.0 kg *a.i.*/ha applied as pre-emergence and hand weeding was done at 40-45DAS	No weeding	Full gap
Irrigation	Nill	Nill	Nill
Insect management	*Helicoverpa armigera* control by IPM including insecticide and sex pheromone trap	Non judicious use of insecticides	Partial gap
Diseases management	Thiophanate methyl - post-emergence application @1.0 kg/ha	Non judicious use of fungicides	Partial gap
Technical guidance	Time to time	Nill	Full gap

by random crop cutting method and analyzed by using simple statistical tools. For the study, technology gap, extension gap and technology index were calculated as suggested by Samui *et al*. (2000) and Kumar (2014) as per formula given below:

$$\text{Per cent increase yield over farmers practice} = \frac{\text{Demonstration yield} - \text{Farmers yield}}{\text{Farmers yield}} \times 100$$

District yield gap (%) =

$$\frac{\text{Demonstration yield - District yield}}{\text{Demonstration yield}} \times 100$$

State yield gap (%) =

$$\frac{\text{Demonstration yield - State yield}}{\text{Demonstration yield}} \times 100$$

Potential yield gap (%) =

$$\frac{\text{Potential yield - Demonstration yield}}{\text{Potential yield}} \times 100$$

Extension gap (q/ha) =

Demonstrated yield - Farmers yield

Technology gap (q/ha) =

Potential yield - Demonstrated yield

Extension gap (q/ha) =

Demonstrated yield - Farmers yield

Technology index (%) =

$$\frac{\text{Potential yield - Demonstration yield}}{\text{Potential yield}} \times 100$$

Net return (Rs./ha) =

Gross return (Rs./ha) - Cost of cultivation (Rs./ha)

$$\text{Benefit/Cost ratio} = \frac{\text{Gross return}}{\text{Cost of cultivation}}$$

Additional cost (Rs/ha) =

Improved technology cost - Farmer practice cost

Additional return (Rs/ha) =

Improved technology return - Farmers' practice return

Effective gains (Rs/ha) =

Additional return - Additional cost

RESULTS AND DISCUSSION

Productivity of chickpea

Results of 325 demonstrations of CFLDs observed in 130 ha area conducted during *Rabi* season from 2016-17 to 2022-2023 (7 consecutive years) in 26 villages of 8 blocks *viz.,* Goradih, Kahalgaon, Nathnagar, Pirpainti, Sabour, Sanhaula, Shahkund and Sultanganj under Bhagalpur district (Table 4) revealed that the average yield of chickpea under improved technology of CFLDs range from 10.75 to 15.71 q/ha as compared to 9.14 to 11.32 q/ha in existing farmers' practices (control plot). Average yield of 325 demonstrations of seven years was 13.87 q/ha from improved technology whereas; the average yield from existing farmers' practices was 10.15 q/ha. It was also observed that the improved technology (CFLDs) increased yield from 17.61 to 53.7% (with an average of 36.53%) over farmers' practice. It might be due to the adoption of improved high yielding varieties, seed treatment, proper weed management practices, recommended dose of fertilizers, insect pest and disease management and other agronomical practices as compared to control (existing farmers practice). The results clearly indicate the positive effects of CFLDs over the existing farmer's practices toward enhancing the yield of chickpea. The result is also in close conformity with the findings of Mauriya *et al.* (2017); Singh *et al.* (2020) and Dhillon *et al.* (2021).

District, state and potential yield gap minimized analysis

It is the extent to which the yield gap at different level, *i.e.* district, state and potential yield levels were compensated because of the yield advantages obtained from the demonstrations of improved technology. On the basis of seven years data from 2016-17 to 2022-23 it was observed that the district yield gap was minimized from 18.85 to 59.39% with an average of 39.77%, whereas, it was from 17.36 to 32.09 with an average of 23.74% under state yield gap and from 23.00 to 46.25% with the mean of 33.82 % in potential yield gap minimization. It might be mainly due to the timely sowing of improved varieties in residual moisture with recommended seed rate, seed treatment with *Trichoderma viride*, chloropyriphos and bio-fertilizers (*Rhizobium* and PSB cultures), balance dose of fertilizer application, timely weed management and suitable plant protection measures. The results indicated that the cluster front line demonstrations have given a good impact over the farming community of Bhagalpur district as they were motivated by the new agricultural technologies applied in the cluster front line demonstration plots. The minimized potential gap is an indicative for adoption of need and situation based specific adaptive trials along with updating the scientific knowledge of production technologies among the farmers. The similar results have also been reported by Dubey *et al.* (2018); Mauriya *et al.* (2019) and Singh *et al.* (2020).

Technology and extension gaps

The data presented in Table 4 reveal that the technological yield gap for the seven years ranged from 4.60 to 9.26 kg/ha with an average of 7.13 kg/ha. The technological yield gap observed may probably be due to variation in the soil fertility status, agronomical practices, managerial skills of individual farmer's and the climatic situation of the area. Since the difference between potential and demonstration yield is the technology gap, therefore, the site specific recommendations are necessary to bridge these gaps. The findings are in line with that reported by Srivastava *et al.* (2017).

The difference between demonstration yield and the existing farmers practice yield is known as extension gap. The perusal of seven years mean data indicated that the extension gap from the technological interventions through CFLD was found to be 3.72 q/ha and range from 1.61 to 5.29 q/ha (Table 4). There is a need to motivate, aware and trained the farmers for adoption of improved technology of crop production with high yielding varieties through extension activities to narrow down the extension gap. An intensive use of the latest production technologies with high yielding varieties will subsequently change this alarming trend of galloping extension gap. These results corroborate with the results of Arunkumar *et al.* (2023) in groundnut.

Technology index

The technology index generally shows the feasibility of the technology at farmers' field. The lower value of index indicates the higher feasibility of technology. The data of Table 4 revealed that the technology index for the seven years (2016-17 to 2022-23) ranged from 23.00 to 46.25%, with an average of 33.82%. The similar finding was observed by Reager *et al.* (2020) in green gram.

Economic analysis

The major economic indicators *viz.* total cost of cultivation, gross return, net return and B:C ratio were calculated based on prevailing market price of inputs and outputs for both the CFLD (improved technology) and existing farmers practice during 2016-17 to 2022-23 (Table 5). On the basis of seven years average data, higher gross return (Rs. 75525/ha), net return (Rs. 48993/ha), benefit cost ratio (2.85) and effective gain (Rs. 17376 /ha) with improved technologies demonstration in CFLDs as compared to existing farmer's

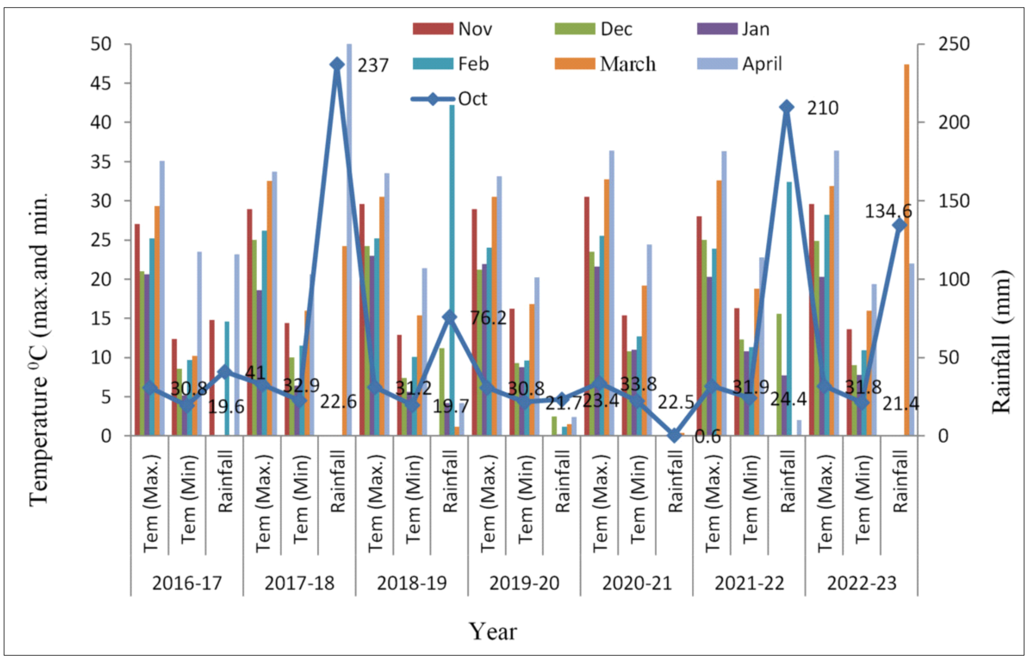

Fig 1: Monthly max. and min. temperature (°C) and rainfall (mm) during crop period.

Table 3: Details of technology demonstrated in chickpea CFLDs during 2016-17 to 2022-23.

Variety	GNG-1581 (2016-17 to 2017-18), PG-186 (2017-18 to 2018-19 and 2020-21 to 2021-22), GCP-105 (2019-20) and RVG 202 (2022-23)
Seed treatment	Seed treatment with *Trichoderma viride* @ 5.0 ml or g/kg seed, Chloropyriphos 20% EC @8.0 ml/kg seed, *Rhizobium* culture @ 20 g or 5 ml/kg seed, PSB culture @20 g or 5 ml/kg seed
Seed rate	75 kg/ha on the basis of seed size (small seeded)
Fertilizer dose	Balance dose of fertilizers (20 kg/ha N + 40-50 kg/ha P) applied as basal
Weed control-	Pendamethaline - pre-emergence application @ 1.0 kg *a.i.*/ha
Disease control-	Thiophanate methyl - post-emergence application @1.0 kg/ha
Insect control-	*Helicoverpa armigera* control by IPM including insecticide and sex pheromone trap

Table 4: Impact of improved technologies under CFLDs on yield and yield gap of chickpea.

Year	CFLDs varieties	Demo area (ha)	No. of farmers (q/ha)	FP yield yield (q/ha)	Demo yield (q/ha)	District yield (q/ha)	State yield (q/ha)	Potential yield (q/ha)	Yield gap minimized (%)			% increase yield over FP	Extension gap (q/ha)	Technology gap (q/ha)	Technological index (%)
									District	State	Potential				
2016-17	GNG-1581	30.0	68	9.59	14.74	8.26	11.20	24.00	43.96	24.02	38.58	53.70	5.15	9.26	38.58
2017-18	PG -186	19.0	40	10.36	14.39	6.38	11.54	20.00	55.66	19.81	28.05	38.90	4.03	5.61	28.05
	GNG-1581	11.0	26	10.42	15.71	6.38	11.54	24.00	59.39	26.54	34.54	50.77	5.29	8.29	34.54
2018-19	PG -186	20.0	88	11.32	15.40	8.92	11.99	20.00	42.08	22.14	23.00	36.04	4.08	4.60	23.00
2019-20	GCP-105	10.0	21	9.14	10.75	6.91	7.30	20.00	35.72	32.09	46.25	17.61	1.61	9.25	46.25
2020-21	PG-186	10.0	32	9.45	12.73	10.33	10.52	20.00	18.85	17.36	36.35	34.71	3.28	7.27	36.35
2021-22	PG-186	10.0	46	10.17	13.43	8.50	10.53	20.00	36.71	21.59	32.85	32.06	3.26	6.57	32.85
2022-23	RVG 202	20.0	69	10.76	13.82	10.26	10.18	20.00	25.76	26.34	30.90	28.44	3.06	6.18	30.90
Total / mean		130.0	390	10.15	13.87	8.24	10.60	21.00	39.77	23.74	33.82	36.53	3.72	7.13	33.82

Table 5: Impact of improved technologies under CFLDs on economics of chickpea.

Year	Variety	Farmer's practice				Demonstration plot				Additional cost (Rs./ha)	Additional return (Rs./ha)	Effective gains (Rs./ha)	% increase in net return
		Gross cost (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio	Gross Cost (Rs./ha)	Gross return (Rs./ha)	Net Return (Rs./ha)	B:C ratio				
2016-17	GNG-1581	22300	53909	31609	2.42	26450	82924	56474	3.14	4150	29015	24865	78.66
2017-18	PG -186	23629	46341	22712	1.96	25924	64517	38593	2.48	2295	18176	15881	69.92
	GNG-1581	23148	46630	23482	2.02	26133	70466	44333	2.70	2985	23836	20851	88.80
2018-19	PG -186	23717	53998	30281	2.28	26176	74240	48064	2.84	2459	20242	17783	58.73
2019-20	GCP-105	23546	56181	32635	2.38	27322	66217	38895	2.43	3776	10036	6260	19.18
2020-21	PG-186	23755	59544	35789	2.51	27975	79410	51435	2.84	4220	19866	15646	43.72
2021-22	PG-186	23950	57767	33817	2.41	25690	81493	55803	3.17	1740	23726	21986	65.01
2022-23	RVG 202	24386	67004	42618	2.75	26580	84930	58350	3.20	2194	17926	15732	36.91
	Mean	23554	55172	31618	2.34	26531	75525	48993	2.85	2977	20353	17376	54.95

practices. The percentage increase in net return over existing farmer practice (control plot) was the highest (88.80%) in 2017-18 under chickpea variety GNG 1581. Whereas, average net return of seven years under improved technologies demonstration was 54.95% higher than existing farmer's practices. This finding is in corroboration with the findings of Raj *et al.* (2013); Kumar and Mauriya (2014) and Dubey *et al.* (2018).

CONCLUSION

Based on seven years study, it can be concluded that the imparting group discussion, training, campaigns, field days and conducting cluster front line demonstrations on integrated crop management approaches with an improved varieties in chick pea are more effective in reducing the yield gap and increasing the production, productivity and profitability of the farmers. Further, it suggests the active involvement of various agriculture line department and local extension functionaries of agriculture extension systems for adoption of the improved technologies.

Conflict of interest

All authors declare that they have no conflict of interest.

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