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Sustainability of yield and value in blackgram (*Vigna mungo*) through frontline demonstrations

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Abstract

The present study evaluated the sustainability of yield and value in blackgram cultivation by adopting improved production technologies through frontline demonstrations. These were implemented as sole and rice fallow crop cultivation in Tamil Nadu, India, to reduce yield gaps at farmers' fields. The scientific study was conducted in 2020-2021 with 295 demonstrations (118 hectares) using cluster village methodology to examine the effects of extension gap, technology gap and technology index on yield and economics by demonstrating improved technologies. These include mechanized sowing, use of disease-resistant varieties, integrated pest and weed management, seed treatment, crop nutrient boosters and mechanized harvesting. Yield enhancement of 51.55 % was recorded in a demonstrated package of technologies over farmers' practices, primarily due to the adoption of Yellow Mosaic Virus-resistant varieties, effective weed management strategies and foliar sprays like TNAU pulse wonder to boost crop growth. The average extension gap (2.89 q/ha), technology gap (0.87 q/ha) and technology index of demonstrations (11.01 %) were documented, which are mainly due to efforts of multidisciplinary scientists' field visits and farm advisories. A study reported higher weed control efficiency (48-76 %) in demo plots, enhancing demon yield than in control plots. Compared to farmers' plots (Rs. 37075/ha), average net returns in demonstrations were higher at Rs. 66732/ha. The study also disclosed an additional net return (Rs.29657/hectare) with an incremental BCR of 19.95, indicating a significant increase in profitability relative to the investment. The consistently greater Sustainability Yield Index (0.61 to 0.99) and Sustainability Value Index (0.88 to 0.93) in demo plots highlight improved stability and economic value of yields compared to farmer's plots. The latest package of technologies in blackgram paved the way for sustained yield under normal conditions, which are defined as fields with adequate moisture and timely sowing and rice fallow conditions. These advancements improved farmers' livelihoods by increasing net returns and ensuring more stable and predictable yields.

Keywords

blackgram technologies; frontline demonstrations; sustainability yield and value indices; technology gap; weed control efficiency

Introduction

Enriched with metabolites, pulses are a robust second line of defence against various biotic and abiotic stresses. The key metabolites that change several abiotic stresses are proline, glucose, sucrose, galactinol, quercetin, γ-aminobutyric acid (GABA), sugar alcohols and phenolic compounds (1). More than 80 % of the pulses are cultivated in rainfed ecology, supporting more than 40 % of the farming population and two-thirds of livestock in the country. Pulses, a rich source of protein (20-25 %), are central to enhancing the income of rainfed farmers. The government has implemented farmer-centric strategies and programs, such as promoting high-yielding varieties, providing subsidies for seeds and supporting market linkages to harness the potential of pulses. Pulses improve soil biodiversity and intercropping, which, in turn, helps agricultural sustainability. To fulfil the population increase, 39 million tons of pulses are needed by 2050. Among pulses, blackgram contributes to 10 % of total pulses production grown mainly in 10 states of Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Karnataka, Gujarat, Andhra Pradesh, Jharkhand, Tamil Nadu and Telangana (Annual report 2022-2023, DPD, Bhopal www.dpd.gov.in). In Tamil Nadu, blackgram is cultivated in 4.16 lakh ha (9 % contribution to India) with a production of 2.77 lakh tons (10 % contribution) and 666 kg/ha yield. In India, pulses are considered a poor man's protein. Still, the net availability of pulses has come down from 60 g/day/person in 1951 to 55 g/day/person in 2017 and still declined to 44.93 g/day/person in 2021 as per the Directorate of Economics and Statistics, Ministry of Agriculture & Farmers Welfare, Government of India (2021). Therefore, there is a need to identify the gaps to increase the area under pulses and develop location-specific new seed varieties (2). Among pulses, blackgram is a significant crop, contributing 2.84 million tons to India's pulse production during 2021–22, underscoring its importance in the study. In Tamil Nadu, the Cauvery Delta Zone (CDZ) is a primary agricultural zone with 1.45 million ha acreage (11 % of the state area). In CDZ, only one rice crop per year is cultivated in rotation from August to January, followed by black gram grown under no-tillage conditions utilizing residual moisture and nutrients in the soil. In this zone, rice fallow pulses cultivated during December-January contribute to more than 40 % of pulse production in the state. Blackgram, as a rice fallow crop, occupies 1.76 lakh hectares in CDZ, but the yield realized was low, 300-500 kg/ha, compared to the potential yield under irrigated conditions (3). Productivity of rice fallow blackgram is low due to various biotic and abiotic stresses, poor crop management practices and socio-economic constraints (4–5).

Challenges faced by farmers include the unavailability of quality seeds, high pest and disease incidence, insufficient financial support, low market values and lack of result-oriented training and demonstrations (6). To address these issues, Krishi Vigyan Kendra (KVK) Tiruchirappalli, the first KVK in Tamil Nadu, implemented frontline demonstrations (FLDs) on improved production technologies, along with establishing an exclusive seed hub centre for pulses. FLD is a field demonstration technique enabling scientists to directly interact with farmers and extension officials to demonstrate new crop production and protection technologies and collect data on factors that affect crop yields. The research project entitled Impact of KVK Interventions on Minimizing yield gap in pulses under rice fallow and sole crop cultivation in Tiruchirappalli District" was conducted from 2020 to 2021. The research aimed to assess yield and value sustainability through technology gap analysis in blackgram. The goal was to demonstrate the potential of high-yielding cultivars and the adoption of scientific methods compared to traditional farming practices to generate greater financial returns.

Materials and Methods

Study area

To enhance black gram production and productivity through KVK interventions under the National Food Security Mission (NFSM), 295 demonstrations (FLDs and cluster FLDs) were implemented during the study period from 2016-17 to 2020-21, covering seven blocks in Tiruchirappalli district of CDZ, Tamil Nadu.

Improved production technologies demonstrated

Yellow Mosaic Virus (YMV) resistant short-duration black gram varieties, namely, VBN6, MDU1, ADT 6, KKM1 and VBN 8, were assessed through field trials and disseminated yield-maximizing technologies such as seed rate optimization, seed drillsowing, seed treatment with biocontrol agents and biofertilizers, foliar spray of diammonium phosphate (DAP), application of crop booster TNAU pulse wonder, weed management and integrated pest and disease management practices through field days, leaflets, folders, All India Radio (AIR) messages and training. The technologies adopted in farmers and demonstration fields are shown in Table 1.

Analysis of impact yield

It refers to the comprehensive evaluation of outcomes resulting from various activities and the overall net effect of these activities, typically conducted by any agency in the context of farmers' economic and social standing (7). The impact yield gives the yield enhancement of demonstrated plots over control plots (farmers' plots) and is calculated using the following formula in Equation 1.

$$\text{Impact yield} = \frac{\text{Yield of demo plot - Yield of farmer plot} \times 100}{\text{Yield of farmer plot}} \qquad \text{(Eqn. 1)}$$

Yield of demo plot–yield obtained by adopting improved practices

Yield of farmer plot–yield obtained by adopting farmers' traditional practices

Analysis of extension gap, technology gap and technology index

Black gram potential yield and demonstration plot yield are compared to calculate the technology index, extension gap and technology gap, which are then used to evaluate the yield gap. The comparison involved evaluating demo plot yield against the district average yield and yield obtained through traditional farmers' practices, mainly to showcase the benefits of improved practices. The technology index measures the feasibility of adopting yield-maximizing technologies and high-

Table 1. Improved production technologies demonstrated in blackgram in comparison with farmers practices

Problems identified	Farmers practices (control)	Improved Production technologies demonstrated
Lack of awareness of YMV-resistant varieties	Age-old, unrecommended poor, yielding varieties	High yielding and YMV resistant varieties VBN6, MDU1, ADT 6, KKM1and VBN 8
Lack of technical know-how	Unawareness of the latest technical	Yield-maximizing technologies demonstrated
Infestation by yellow mosaic virus	Spray any insecticide as per the guidance of the pesticide shop dealer	Recommended YMV resistant varieties VBN6, MDU1, ADT 6, KKM1and VBN 8
Weed infestation	Spray Pendimethalin @ 800- 900 ml/acre with hand sprayer	Recommended for hand weeding @ 15 DAS or use of Pendimethalin @ 400 ml/acre
Nutrient management	Farmers apply DAP 50 kg/acre.	Recommended DAP - 43 kg Urea - 9 kg and Potash - 6 kg per
Poor yield due to moisture stress	Lack of awareness on crop boosters	Foliar spraying of TNAU pulse wonder @ 2kg/acre at 15 days
Lesser market price	Small and poor-quality seeds fetch a lower market price	Big and bold seeds of almost uniform size fetched high market price

yielding on farmers' fields. The feasibility of farmers adopting improved technologies is higher when the technology index value is lower. The size of the technological divide impacts the percentage-based technology index (it is the gap in farmers' ability to access the latest technologies digitally to enhance yields). This analytical approach offers a comprehensive understanding of the effectiveness and success of KVK interventions in improving agricultural outcomes for pulse growers in the region. The applied and the technology gap, extension gap, technology index, indices on sustainability yield and value were studied to evaluate and quantify this influence and the formula is given in Equation 2-4.

$$\text{Extension gap} = \text{Yield in Demo plot} - \text{Yield in Farmer plot} \quad \text{(Eqn. 2)}$$

$$\text{Technology gap} = \text{Potential yield} - \text{Demo plot yield} \quad \text{(Eqn. 3)}$$

$$\text{Technology index} = \frac{\text{Potential yield - Demo plot yield} \times 100}{\text{Potential yield}} \quad \text{(Eqn. 4)}$$

Analysis of sustainability yield indices

Based on the data recorded on yield and net returns from the demo and farmers plots, the Sustainable yield index (SYI) and sustainable value (SVI) were calculated using the formula given in Equation 5 (8).

$$\text{SYI/SVI} = \frac{Y - O}{Y_{max}} \quad \text{(Eqn. 5)}$$

whereas,

Y_{max} Maximum yield / maximum net return

Y Estimated average yield/Net return of practices over the year

O Standard deviation"

In addition, standard deviation (SD) and coefficient of variation (CV %) were analyzed to calculate the SYI and SVI in this study.

Analysis of weed control efficiency (WCE)

It is worked out by considering the reduced weed dry weight in the treated/demo plot over the weed dry weight in the unweeded check /control plot (Farmer practices). It is expressed in %. WCE is calculated per the formula in equation 6 (9).

$$\text{WCE} = \frac{\text{WC - WT} \times 100}{\text{WC}} \quad \text{(Eqn. 6)}$$

Where WC = Weed dry weight in control (unweeded) plot

WT= Weed dry weight in the treated plot

Data on yield qualities, including technology gap, extension gap, technology index, sustainability yield index, sustainability value index and weed control efficiency and economics, were examined in the research. The scientists of KVK regularly visited the fields and monitored periodically and collected yield parameters data at harvest time from both demonstrated and farmer plots. The details on cultivation cost and net profit have been collected from farmers in the research area to calculate the benefit-cost ratio (BCR).

Results and Discussion

Effect of extension gap on impact yield

The study recorded an average yield of 8.77 q/ha in demo plots and 5.88 q/ha in farmers' plots during the five-year study period in blackgram cultivation, resulting in an impact yield of 51.55 % (Table 2). This enhanced yield was achieved through the adoption of demonstrated technologies like YMV resistant varieties VBN6, MDU1, ADT 6, KKM1and VBN 8, foliar spraying of DAP, TNAU pulse wonder, 1 % urea, 1 % Potassium chloride (KCl) spray, weed management practices and Integrated Pest Management practices (Fig. 1). The highest impact yield of 81 % occurred during 2017-18 due to introducing the YMV-resistant variety VBN 6 and the enhanced production by establishing seed hub centres. The seed hub centre is a project of the Indian Council of Agricultural Research that involves Krishi Vigyan Kendras to produce pulses with the motive of meeting the demand for pulses, reducing imports, developing infrastructure for storing, processing, certifying and registering seeds and producing seeds of farmers' preferred varieties. The least impact yield was recorded as 14.70 % in the year 2020-21 for the reason of the change of variety from VBN 6 to improved variety VBN 8 and farmers found it not easy to switch over from the established ruling variety of VBN 6 to VBN 8 mainly due to limited awareness about VBN 8. The gap for extension varied from 1.16 to 4.39 q/ha during the demonstration period, with 2.89q/ha as average. The highest extension gap of 4.51 q/ha was recorded for the YMV-resistant blackgram variety VBN6 and the lowest extension gap of 1.16 q/ha for the new variety VBN 8, which showed the strong Extension efforts made through FLDs and

Cluster FLDs in reaching the farmers with latest blackgram technologies. Higher yield and net returns were recorded in demo plots over control plots from 2016-17 to 2020-21 (Fig. 1). Similar findings have been reported in blackgram and sesame , where similar technologies and practices resulted in improved yields (3, 10-14).

Effect of technology gap

The difference between the potential crop yield and the demonstration yield varies from -0.15 to -1.18 q/ha with an average of -0.87 q/ha (Table 2). In general, the technology gap exists mainly due to the differences in soil fertility, crop varieties, climatic influence and the farmers' non-cooperation in demonstrating. The present study showed that using technology among farmers improved their understanding of newer techniques. Location-specific cultivation practices disseminated among the farmers were spraying of Naphthalene Acetic Acid (NAA) and salicylic acid, amendments for soil surface crusting, soil application of TNAU micronutrient mixture, zinc sulphate ($ZnSO_4$) under irrigated conditions, mechanized sowing behind seed drill, foliar spraying of KCl and TNAU pulse wonder and seed treatment before sowing with chemicals, biofertilizers and biocontrol agents, weedicide application and Integrated Pest Management practices. Similar findings have been reported, which suggest that strengthening the extension system, promoting on-farm trials and motivating farmers to adopt the latest technologies will narrow the existing technology gap (14-17).

Technology index

The lower the value of the technology index, the higher the adoption rate of improved technologies in blackgram. The values for the technology index in demonstrated plots ranged from -1.90 % to 24.18 % (average -11.01 % in Table 2). Lower values of the technology index showed the feasibility of demonstrated technologies in farmers' fields, leading to higher net returns. This was achievable through cluster village demonstrations and mass awareness campaigns, off-campus training and farm advisories by KVK scientists in collaboration with Department of Agriculture officials and farmers consistently (Fig. 3). Similar findings were reported in sesame in which the technology index ranged from 17 to 27 percent (14) and 6.72 to 49 percent in redgram (17). There is a need to reduce the gap by introducing high-yielding varieties and location-specific farm technologies under Cluster FLDs.

Effect of weed infestation on yield

Weed infestation, especially in rice fallow blackgram, significantly reduced yield. The pre-dominant grassy weeds in blackgram are *Echinochloa crus-galli* (L.) and *Echinochloa colona* (L) and the dominant sedge is *Cyperus difformis (L).* Higher weed density of 10 to 32.1 m/m^2 was recorded in farmers' plots; demo plots ranged from 3.23 to 8.9 m/m^2. Following recommended weed management practices in demo plots, like hand weeding, timely application of herbicide and correct dosage of weedicide (Fig. 4), controlled the weed growth. Weed control efficiency was

Table 2. Evaluation of improved production technologies in blackgram through FLDs (n=295)

Year	No.of demos	Area in hectares	Variety		Yield (q/ha)		Impact yield over the control (%)	Extension gap (q/ha)	Technology gap (q/ha)	Technology index (%)
			Demo	Control	Demo	Control				
2016-17	60	24	VBN 6, MDU 1 + seed drill	VBN 5, ADT 3	9.08	5.68	60.06	3.41	-1.18	-14.94
2017-18	30	12	VBN 6	VBN 5, ADT 3	9.81	5.42	81.00	4.39	-1.91	-24.18
2018-19	55	22	ADT 6, KKM 1, VBN 6	VBN 5, ADT 3	8.05	5.27	52.11	2.79	-0.15	-1.90
2019-20	50	20	VBN 6, ADT 6	VBN 5, ADT 3	8.06	5.35	49.88	2.71	-0.16	-1.96
2020-21	100	40	VBN 8	VBN 6, ADT 5	8.86	7.7	14.70	1.16	-0.96	-12.09
Total	295	118		Average	8.77	5.88	51.55	2.89	-0.87	-11.01
				SD	0.74	1.03	23.98	1.18	0.74	9.42
				CV %	8.47	17.45	46.52	40.75	-85.21	-85.53

* SD-standard deviation; CV-coefficient of variation;

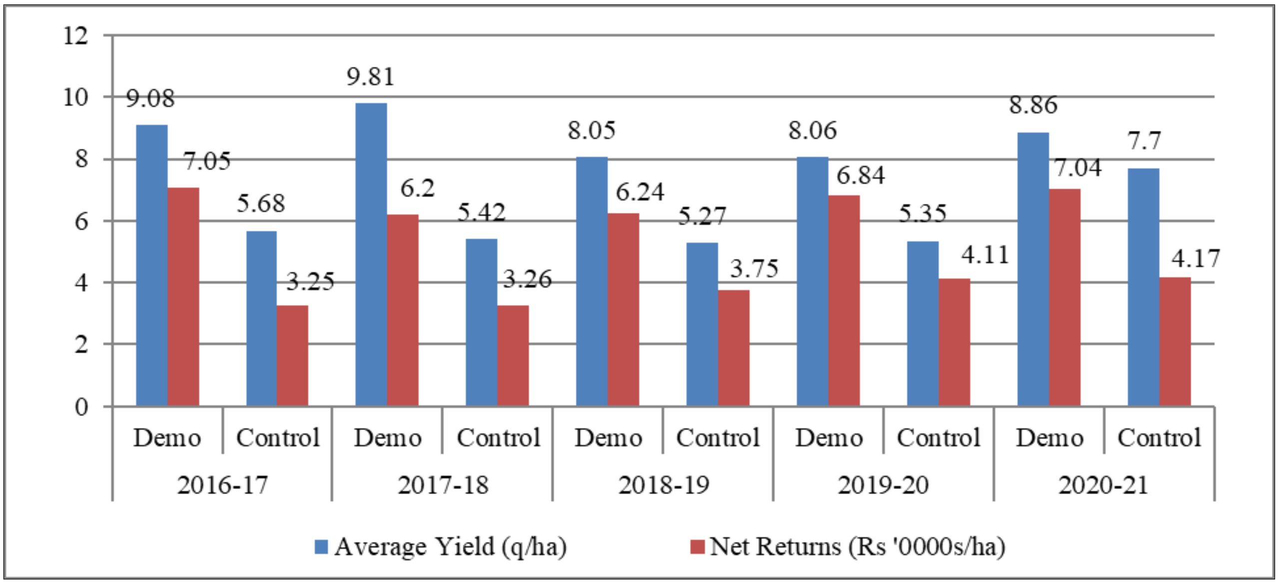

Fig. 1. Evaluation of FLDs on yield and economics in blackgram

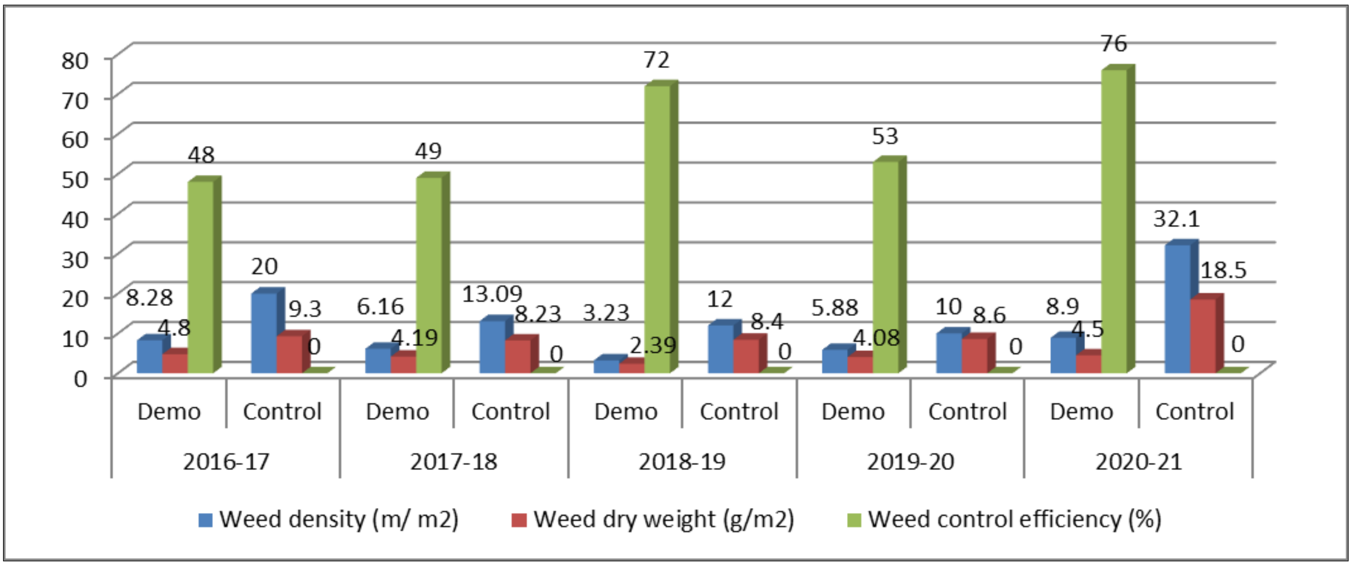

Fig. 2. Effect of weed control efficiency in blackgram

Fig. 3. Photos on demonstration of blackgram production technologies

observed to the tune of 48 % to 76 % with an average of 59.6 % compared to farmers' plots (Fig. 2). The average weed intensity in demo plots recorded was 6.49 m/m^2 when compared to farmers' plots 17.44 m/m^2 while the weed dry weight was to the tune of 3.99 and 10.61 respectively in demo and farmers plots Table S1. These observations depicted that weed-free plots certainly yield higher yields.

Analysis of economic returns

Using current input and output costs at the time of the study, the economic viability of demo plot practices relative to farmer plot practices was computed (Fig. 4). The economic returns in the study depended mainly on farmers' yield in demo and control plots, cost of inputs utilized, wage rates of labour and existing market price fluctuations. Table 3 clearly shows that demonstration plots had higher average cultivation costs (Rs. 38120/ha), increased gross returns (Rs. 104852/ha) and higher net returns (Rs. 66732/ha), with an average BCR of 2.75, compared to farmers' plots (Rs. 36515/ha, Rs. 73504/ha and Rs. 37075/ha, respectively), with an average BCR of 2.01. The study also disclosed an average gross cost of cultivation incurred additionally to farmers of Rs.1605 per hectare for 295 demonstrations in five years. By adopting improved technologies in each year, farmers gained on an average additional gross return (Rs. 31262/ha) and net returns (Rs.29657/ha) with an incremental BCR of 19.95 during the five-year study period against farmer's plot (Table 3). The incremental BCR is calculated based on the additional gross cost and additional gross returns and hence found to be higher over the years. Similar conclusions were stated in redgram, moong, urd and groundnut crops, signifying the demonstration's economic viability and higher profitability (17-20). The study revealed that transferring various improved blackgram production technologies through multiple extension methods in fields remarkably enhanced the farmers' returns under normal and rice fallow conditions.

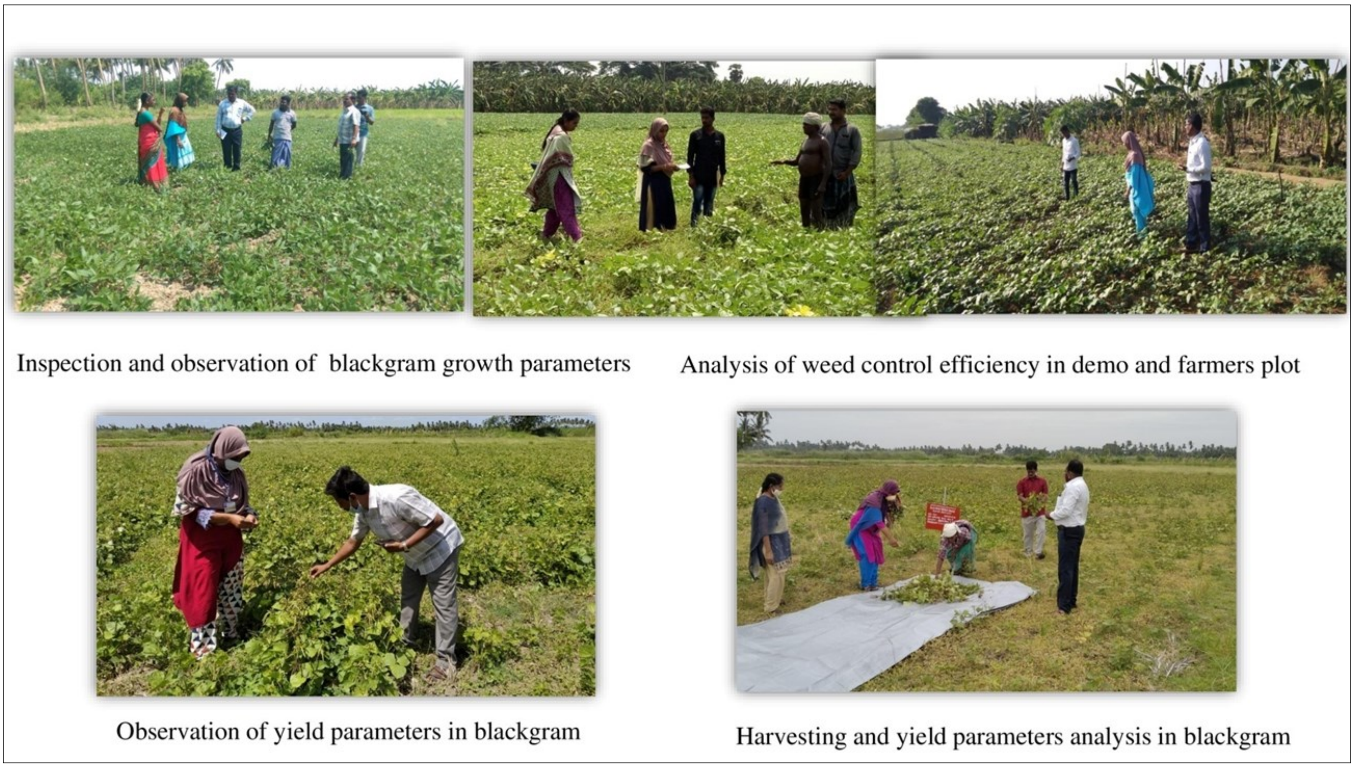

Fig. 4. Photos on observation of growth, weed infestation and yield parameters in blackgram

Table 3. Impact of improved production technologies under FLDs on the economics of blackgram (n=295)

Year	Cost of cultivation (Rs/ha)		Gross returns (Rs/ha)		Net returns (Rs/ha)		BC ratio		Additional returns in improved practices			
	Demo	Control	Demo	Control	Demo	Control	Demo	Control	Additional cost of cultivation (Rs/ha	Additional Gross returns (Rs/ha)	Additional Net returns (Rs/ha)	Incremental BC ratio
2016-17	35500	34125	106012	66652	70512	32527	2.99	1.95	1375	39360	37985	28.63
2017-18	37800	36000	99800	68550	62000	32550	2.64	1.90	1800	31250	29450	17.36
2018-19	38650	36900	101000	74400	62350	37500	2.61	2.02	1750	26600	24850	15.20
2019-20	39100	37400	107500	78500	68400	41100	2.75	2.10	1700	29000	27300	17.06
2020-21	39550	38150	109950	79850	70400	41700	2.78	2.09	1400	30100	28700	21.50
Average	38120	36515	104852.4	73590.4	66732.4	37075.4	2.75	2.01	1605	31262	**29657**	**19.95**

Indices on sustainability yield and sustainability value

Demonstration plots recorded higher values for sustainability indices on yield and value than farmers' plots. The Sustainability Yield Index ranged from 0.61 to 0.99 in the demonstration plot, while the farmers' plot recorded from 0.57 to 0.90. The Sustainability Value Index was 0.88 to 0.93 in the demo plot and 0.84 to 0.89in the farmer plot (Table 4). The standard deviation and coefficient of variation values have been significant in demo plots compared to farmers' plots (Table 4). This difference may be due to variations in yield between demonstration plots, which used improved production technologies and farmers' plots, leading to greater sustainability in the demo plots. A similar view was expressed in pulses and groundnuts, where improved technologies also resulted in greater sustainability (12,20).

Table 4. Effect of Improved Production technologies on seed yield, net returns, SYI and SVI in black gram

Year	2016-17		2017-18		2018-19		2019-20		2020-21	
	Demo	Control	Demo	Control	Demo	Control	Demo	Control	Demo	Control
Seed yield (q/ha) Max	9.7	6.1	9.85	5.71	9.89	6.78	9.99	6.8	10.1	9.05
Seed yield (q/ha) Min	8.45	5.25	9.76	5.12	6.2	4.05	6.12	3.9	7.62	6.35
Mean Seed yield (q/ha)	9.08	5.68	9.81	5.42	8.05	5.42	8.06	5.35	8.86	7.70
SD	0.63	0.42	0.04	0.29	1.85	1.37	1.94	1.45	1.24	1.35
CV %	6.89	7.49	0.46	5.45	22.93	25.21	24.02	27.10	14.00	17.53
Net returns (Rs/ha) Max	74194	35380	65200	35420	64600	39600	72900	44100	74150	44800
Net returns (Rs/ha) Min	66830	29674	58800	29680	60100	35400	63900	38100	66650	38600
Mean Net returns (Rs/ha)	70512	32527	62000	32550	62350	37500	68400	41100	70400	41700
SD	3682	2853	3200	2870	2250	2100	4500	3000	3750	3100
CV %	5.22	8.77	5.16	8.82	3.61	5.60	6.58	7.30	5.33	7.43
SYI	0.87	0.86	0.99	0.90	0.63	0.60	0.61	0.57	0.75	0.70
SVI	0.90	0.84	0.90	0.84	0.93	0.89	0.88	0.86	0.90	0.86

*Demo-yield maximizing technologies; Control- farmers practices; SD-standard deviation; CV-coefficient of variation; SYI-sustainability yield index; SVI-sustainability value index

Conclusion

The study concludes that innovative interventions and effective utilization of blackgram inputs at critical stages contribute to increased yield and economic returns. Through the cluster village approach, the yield gap can be reduced through frontline demonstrations at farmers' fields. This method leads to a shift in farmers' adoption behaviour, promoting sustainable yields and profits. The increased yields observed in demonstrations complemented the narrowing gap in extension and technology and generated a good attitude among farmers. A lower value of the technology index signifies the successful performance of yield-maximizing technologies, fostering a positive relationship and confidence between farmers and extension officials. These findings gave researchers fresh insights into blackgram cultivars suitable for rice fallow and rainfed conditions, which benefitted especially small and marginal farmers.

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Authors' contributions

NAKAH carried out the main research, methodologist and data analyzer and drafted the original manuscript. VAA participated in writing the discussion for the blackgram seed production inputs. GA contributed through blackgram sowing mechanization techniques. MR participated in writing the discussion through Integrated Pest Management technologies. TS performed the weed management statistical analysis. SE participated in the discussion writing. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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