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Summer Greengram Cultivation Demonstrates Efficient Energy Dynamics and Economic Viability

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ABSTRACT

The frontline demonstrations of summer greengram were conducted in district Moga, Punjab, India during summer (March–June, 2017, 2019 and 2021) to evaluate the performance of recommended production technologies with farmers' practices. The data collected was further subjected to analyse the block wise energy footprints of the summer greengram to study the ecological and economical variability. The results revealed that demonstration plots recorded significantly higher seed yield and better B:C in demonstration plots than FPP in all blocks. In 2017 and 2019, highest value of performance indicator such as extension gap was observed in block Moga I followed by Nihal Singh Wala and Moga II with lowest value in Baghapurana block. In 2021, highest value of extension gap was recorded in Moga II block followed by Moga I and Baghapurana. The technology gap was recorded less than one in all the blocks during 2017 and 2019 which indicates that demonstration plots realised higher seed yield than potential yield. In 2017, lowest technology index was recorded in Moga I block (-0.14) followed by Nihal Singh Wala (-0.13) and Baghapurana (-0.12). In 2021, minimum value was recorded in Nihal Singh Wala (-0.08) block. Over the years, demonstration plots registered significantly different energy footprints such as energy input, energy output, energy use efficiency, energy productivity, net energy and energy profitability than FPP. From the data, it can be concluded that cultivation of summer greengram in all the blocks of district Moga is economically as well as ecologically viable with highly efficient energy footprints.

KEYWORDS: Summer greengram, seed yield, performance indicator, energy footprints

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1. INTRODUCTION

The word "Pulse" was originated from the Latin word "Puls" meaning pottage referring to seeds boiled to make porridge or thick soup (Kanavi et al., 2020). Pulses as one of the cheapest sources of protein contain about 18–25% of protein (Dayanand et al., 2014) contribute 11 % of the total intake of proteins in India (Reddy, 2017). In India, pulses are cultivated on an area of 28 mha with total production of 25.46 mt with productivity at 885 kg ha^{-1}. In Punjab, total pulses are grown on an area of 33000 ha with total production of 30000 t and productivity of 0.90 t ha^{-1}. Pulses contribute by 22 and 8% in total food grain production of India in terms of area and production, respectively (Anonymous, 2021). Greengram is a short-duration, cleistogamous legume belonging to the family *Leguminaceae* (Kanavi et al., 2023). Being short in duration and ability to withstand heat and drought stress, it is very much suitable to include in a number of cropping systems (Patil et al., 2021 and Nayak et al., 2022). Greengram helps in soil fertility restoration by biological atmospheric nitrogen fixation (Wanga et al., 2017 and Kaur et al., 2021). Prevailing gap between production potential and the actual yield levels may be due to partial adoption of recommended package of practices (Amuthaselvi et al., 2023) and is very challenging in agricultural extension (Singh et al., 2019), which sometimes results in less adoption of technologies (Singh et al., 2025). The gap between scientists' recommendations and farmers' actual adoption of modern agricultural practices is a common challenge in agricultural extension (Singh et al., 2019). It is needed to make stronger extension services for educating the cultivators in the implementation of improved technology (Parmar et al., 2017). The front line demonstrations are an important aspect to transfer the latest technologies to farmer fields in which farmers become aware of recent techniques under real farming situations at their own fields (Singh and Sharma, 2018). FLDs show a significant positive and provide an opportunity to the researchers to demonstrate the productivity potential and profitability of newly developed technology (Teggelli et al., 2015). It acts as a powerful tool for assessing and transferring technology to enhance agricultural production (Sangwan et al., 2021; Singh and Tetarwal, 2022; Ali et al., 2023). The main objective of FLDs is to promote the improved production technologies, critical for innovation diffusion and enhancing productivity (Verma et al., 2014 and Singh et al., 2024). By demonstrating the practical benefits of scientific practices, frontline demonstrations serve as an essential mechanism for closing the gap between research and practice, ultimately leading to higher agricultural yields and enhanced food security (Singh et al., 2025). The technology index indicates the feasibility of new technology at the field level, as it is an essential tool for judging the adoption and impact of different technologies (Kumar et al., 2023). Less grain yield in greengram can be attributed to a number of factors worldwide, including a significant portion of India's pulse cultivation which includes using seed saved by the farmers (Ullah et al., 2020), inefficient crop management practices (Aravinth et al., 2023; Ayerdi and Marraccini (2022). To address various production technology and weather related issues, Krishi Vigyan Kendra, Budh Singh Wala, Moga conducted FLDs of summer greengram by providing critical input, technical know-how, and need based on the spot guidance. The results were complied to compare the relative performance of demonstration plots and farmers' practice. This Manuscript represents the descriptive analysis of the productivity and economics of the summer greengram in the frontline demonstrations conducted in 2017, 2019 and 2021 in district Moga.

2. MATERIALS AND METHODS

Krishi Vigyan Kendra (KVK), Budh Singh Wala, Moga, Punjab laid down the cluster frontline demonstrations of summer greengram in district Moga during summer (March–June, 2017, 2019 and 2021). The year wise details of the frontline demonstrations such as crop, variety and potential yield of crops are given below:

Table 1: Number of frontline demonstrations of summer greengram and potential yield

Year	Crop	Variety	No. of demonstrations	Potential yield (kg ha^{-1})
2017	Summer greengram	SML 668	100	1125
2019	Summer greengram	SML 832	92	1150
2021	Summer greengram	SML 1827	60	1250

While conducting demonstrations, farmers were guided for improved production technologies (Table 2) through training camps, farm literature and personal contact. At each farmer field, a check plot containing farmers' practices was maintained parallel to the demonstration plot.

All the demonstrations were regularly visited by KVK scientists to supervise the critical farm operations and crop health. Extension activities like group meetings and field days were organized at the demonstration site with an objective to spread the outcomes of the technology among other farmers of the area. The data regarding crop yield, cost of cultivation, gross returns etc. were collected from both demonstration and check plots which were further

Table 2: Details of farmers' practices (FPP) and intervention in demonstration plot

Particulars		FPP	Intervention
Variety		Local	Improved variety
Time of sowing		March-April	As per recommendation
Method of sowing		Broadcasting	Line sowing
Seed rate (kg ha^{-1})		37.5-45	30-37.5
Fertilizer application (kg ha^{-1})	After wheat	Urea-125-150 DAP-75-125	Urea-28 Single super phosphate- 250
	After potato	Urea-75-100 DAP-50-75	No fertilizer application
Weed management		Use of non-recommended herbicides	Hand weeding at 3–4 weeks after sowing
Pest and disease management		Foliar spray of insecticides	Adoption of Integrated pest management (IPM) approach

used to calculate various indices and ratios (Samui et al., 2000) as given below:

Extension gap=Demonstration Yield-Farmers yield

Technology gap=Potential yield-Demonstration yield

Technology index=Technology gap/Potential yield×100

Economic analysis of both demonstration as well as check plots was performed to check the economic viability and profitability of the technologies demonstrated. Benefit:cost ratio was derived by calculating the cost of cultivation, gross returns, net returns (Table 3).

B:C=Net returns/Cost of cultivation

The energy input was estimated by addition of partial energies of manpower labour, fuel (petrol and diesel), irrigation, machinery, inorganic fertilizers and agro-chemicals, expressed as MJ ha^{-1}. Other indices were calculated using the formulas given below:

Energy output (MJ ha^{-1})=Productivity (kg ha^{-1})×Energy coefficient (Cheng et al., 2023)

Net energy (MJ ha^{-1})=Energy output (MJ ha^{-1})-Energy input (MJ ha^{-1}) (Cheng et al., 2023)

Energy use efficiency=Energy output (MJ ha^{-1})/Energy input (MJ ha^{-1}) (Cheng et al., 2023)

Energy productivity (kg MJ^{-1})=Productivity (kg ha^{-1})/ Energy input (MJ ha^{-1}) (Cheng et al., 2023)

Energy profitability=Net energy (MJ ha^{-1})/Energy input (MJ ha^{-1}) (Kizilaslan, 2009)

The statistical analysis of the data was performed on OPSTAT online software of CCS HAU, Hisar. The data was run through one way ANOVA to compare the means of the demonstration and control plots.

Table 3: Energy equivalents (MJ unit^{-1}) of inputs and outputs

Resource input	Unit	Equivalent (MJ unit^{-1})	Reference
Seed	kg	14.70	Singh and Mittal, 1992
Labour	Hr	1.96	Mohammadi et al., 2010
Tractor	Hr	62.80	Zangeneh et al., 2010
Nitrogen	kg	66.14	Mohammadi et al., 2010
Phosphorus	kg	12.44	Mohammadi et al., 2010
Potassium	kg	11.15	Mohammadi et al., 2010
Zinc sulphate	kg	20.90	Singh and Mittal, 1992
Herbicide	kg	238.32	Esengun et al., 2007
Insecticide	kg	184.63	Pimentel, 1980
Water	M^3	1.02	Mohammadi et al., 2010
Diesel	L	46.30	Safa and Tabatabaeerfar, 2002
Output	kg	11.25	Soni et al., 2013

3. RESULTS AND DISCUSSION

3.1. Seed yield

Compilation of data on performance of demonstration plots and local practices (Table 4) revealed that improved technologies registered higher seed yield of summer greengram in comparison to farmers' practice over the years in all the blocks. For instance, in 2017, demonstrations plots had 9.05, 8.86, 8.42 and 8.92% higher and significantly different seed yield in Moga I, Moga II, Baghapurana and Nihal Singh Wala block, respectively. Similarly, in 2021, demonstration plots registered significantly different seed yield in all the blocks. For example, in block Moga I, demonstration plot (1131

Table 4: Block-wise productivity (kg ha^{-1}) of summer greengram in the demonstration and FPP plots

Treatment	2017				2019			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	1171	1151	1164	1166	1223	1217	1221	1220
FLD	1277	1253	1262	1270	1357	1346	1349	1350
p=0.05	<.00001	<.00001	<.00001	<.00001	0.00002	<.00001	<.00001	<.00001
SEd	12.33	11.21	13.91	12.37	18.76	17.56	18.06	18.11
Change over FPP (%)	9.05	8.86	8.42	8.92	10.96	10.60	10.48	10.53

Table 4: Continue...

Treatment	2021			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	1056	1042	1049	1053
FLD	1131	1120	1122	1125
p=0.05	0.00477	.003416	0.04229	<.00001
SEd	14.13	14.41	18.36	17.67
Change over FPP (%)	7.10	7.49	6.96	6.84

kg ha^{-1}) recorded 7.10% higher and significantly different seed yield than control plot (1056 kg ha^{-1}). The increase in grain yield in demonstration plots can be attributed to use of improved variety, suitable seed rate and method of sowing, integrated nutrient and pest management practices, which in turn, helped in overall growth and development of crop. In contrast, use of local cultivar, non-judicious use of fertilizers, pesticides, and irrigation water resulted in poor performance of FPP. Results showed the significance of conducting demonstrations at farmers' field by which the actual benefits and prospects of any technology can be assessed under prevailing weather conditions. High grain yield of summer greengram in demonstration plots is in line with Madhushekar et al. (2022) who recorded seed yield of 2659 kg ha^{-1} in demonstration plot which was 12.53 % higher than farmer's practice (2362 kg ha^{-1}). Jaidka et al. (2024) also reported 13.65 % higher seed yield of summer greengram in demonstration plot (895 kg ha^{-1}) than FPP (788 kg ha^{-1}).

3.2. *Benefit-cost ratio (B:C)*

Economic analysis of any factor or enterprise elaborates the financial liabilities as well as assets emerging as an output of the system. As it directly describes the avenues of monitory gains or losses, so the economics of the any crop production programme is the major driving force for wide spread adoption. Compilation of data (Table 5) revealed that frontline demonstrations of all the summer greengram recorded high B:C in all the blocks in all the years in comparison to farmers' practices. For instance, in 2019, demonstration of improved variety of summer greengram

Table 5: Benefit-cost ratio of summer greengram in demonstration and FPP plots

Treatment	2017				2019			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	1.38	1.22	1.31	1.34	1.14	1.02	1.12	1.09
FLD	2.13	2.05	2.13	2.18	2.07	1.95	2.01	2.00

Table 5: Continue...

Treatment	2021			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	1.51	1.39	1.45	1.49
FLD	3.21	3.09	3.15	3.19

registered 81.57, 91.18, 79.46 and 83.49 % higher B:C in block Moga I (2.07), Moga II (1.95), Baghapurana (2.01) and Nihal Singh Wala (2.00), respectively, than FPP. Over the years, in all the blocks, demonstration plots had higher B:C than farmers' practice that can be attributed to better grain yield, less cost of cultivation, which in turn, enhanced the net returns. It means that adoption of improved production technology prove propitious in benefitting the farmers in terms of high monetary returns. From the data it can be concluded that cultivation of improved variety of summer greengram with refined production technologies such bed planting in heavy soils, flat (line) sowing in light soils, intergrated nutrient management, integrated pest management etc. helps enhance the seed yield, reduced cost of cultivation, high net returns, in turn, better B:C. Farmers of the all the blocks can go for adoption of the improved variety in combination with site specific production practices to have enhanced monetary returns as compared to conventional practices. The results of enhancement in B:C in demonstration plot than farmers' practise are in accordance with Jaidka et al. (2024) where demonstration of improved variety of summer greengram (1.37) in Aur block recorded 28.04% higher B:C than FPP (1.07). Balai et al. (2021) also reported that improved technologies resulted in higher B:C (4.88) as compared to local check (4.22).

3.3. Performance indices

3.3.1. Extension gap

Extension gap indicates the extent of farmers' education and need for dissemination of information regarding the given technology. More value of extension gap depicts high level of difference between performance of farmers' practice and technology practised in the demonstration and vice-versa. The compilation of data (Table 6) revealed that during 2017 and 2019, Summer greengram recorded highest value of extension gap in block Moga I followed by Nihal Singh Wala and Moga II. High value of extension gap in Moga I block showed that farmers of the block had lower level of awareness, less technical know-how, less exposure to improved technologies due to which their practice could not perform better as compared to the technology demonstrated. At the same time low value in Baghapurana block depicted better technical skills, better adoption of improved technologies owing to which their crop production practices resulted in better seed yield of summer greengram. In 2021, highest value of extension gap was recorded in Moga II block followed by Moga I and Baghapurana. The data simply depicted a need to concentrate the extension activities or awareness programmes in respective block having high value of extension gap. In other words, it can be said that high value of extension gap in a given area indicates prospects of conducting field demonstrations or extension activities relative to other blocks (Singh and Singh, 2020). The intensification of activities is required to uplift the farmers' skills in the context of improved production technology of all the crops. The results are in line with Jaidka and Brar (2024) who reported that extension gap ranged from 3.83 to 4.4 among the years which clearly depict the superiority of improved production technologies of oilseeds relative to farmers' cultivation practices.

3.3.2. Technology gap

Technology gap indicates the level of cooperation showed by the farmers in adoption and use of new technology practised in the demonstrations. More value of technology gap depicts lesser interest showed by farmers in practising the improved technology and poor performance of improved technology which widens the difference between potential yield and yield obtained in demonstration plot. The data (Table 6) depicted that technology gap was recorded less than one in all the blocks during 2017 and 2019 which concludes that demonstration plots realised higher seed yield than potential yield of the varieties. On the contrary, a decrease in seed yield was observed in demonstration plots than potential yield in 2021. This variation over the years indicates need based, farmer based application of technical knowledge in the fields. One cannot expect same yield trends over the period of time, therefore, there is need to have conduct extension activities or recurrent visits to the farmer fields for better realisation of seed yield. Crop specific, variety specific, region specific planning and execution of extension activities, packages of practices to enhance the performance of improved technologies of all the crops and bridge the gap between potential and demonstration yield

Table 6: Block wise extension and technology indices of demonstrations in district Moga

Block	Extension gap			Technology gap			Technology index		
	2017	2019	2021	2017	2019	2021	2017	2019	2021
Moga I	1.06	1.33	0.75	-1.52	-2.07	1.19	-0.14	-0.18	0.1
Moga II	1.02	1.29	0.79	-1.28	-1.96	1.3	-0.11	-0.17	0.1
Baghapurana	0.98	1.28	0.73	-1.37	-1.99	1.28	-0.12	-0.17	0.1
Nihal Singh Wala	1.04	1.3	1.3	-1.45	-1.99	-0.99	-0.13	-0.17	-0.08

can be minimised (Dash et al., 2021). These findings are similar to the findings of Madhuhekar et al. (2022) who reported that the difference between potential yield and yield of demonstration plots was 648, 1591 and 890 kg ha^{-1} during 2019–20, 2020–21 and 2021–22 respectively.

3.3.3. Technology index

Technology index indicates the feasibility of any technology for cultivation or adoption in a given locality. More value of technology index shows lower possibility of adoption at farmers' fields and vice-versa. Less value in a given location indirectly shows importance of promotional activities in those areas to improve performance and adaptability to existing conditions so that the given technology becomes ecologically and economically viable. In 2017, data on technology index (Table 6) showed lowest technology index in Moga I block (-0.14) followed by Nihal Singh Wala (-0.13) and Baghapurana (-0.12) which indicated the adoption of summer greengram is more feasible in Moga I block followed by Nihal Singh Wala and Baghapurana. Highest value in block Moga II (-0.11) depicted less feasibility which increased the need to plan and conduct farmer education and training programmes to create awareness among the farmers regarding improved variety of summer greengram. The gap in technology index between the blocks can be attributed to the difference in soil fertility status, weather conditions, and insect-pests attack in the crop (Pawar et al., 2018). The analysis of data over the years depicted temporal variation in technology index between the blocks. In 2021, minimum value was recorded in Nihal Singh Wala (-0.08) block. Other three blocks registered similar value of technology index i.e., 0.1. Temporal variation in the technology index indicates need to create awareness among the farmers on regular and recurrent basis.

3.4. Energy footprints

3.4.1. Energy input and output

Analysis of data (Table 7) revealed that cultivation of improved variety of summer greengram significantly lower energy input in comparison to FPP in all the blocks over the years. for instance, in 2021, demonstration plot recorded 19.76, 17.57, 18.51 and 18.68% lower and significantly different energy requirement in Moga I (4807 MJ ha^{-1}), Moga II (5031 MJ ha^{-1}), Baghapurana (4928 MJ ha^{-1}) and Nihal Singh Wala (4903 MJ ha^{-1}), respectively, than FPP. Significantly lower energy requirement in demonstration plots can be attributed to lesser use of inputs such as seed, fertilizer, insecticides etc. for the cultivation of crop than FPP which included non-judicious use of fertilizers as well insecticides and more dependence on external inputs and agrochemicals. Results also indicate that cultivation of summer greengram as per the recommendations of Punjab Agricultural University, Ludhiana is less energy intensive relative to farmers' practice which in turn, justifies sustainability development goal 7 (SDG) of the United Nations. Data on energy output (Table 7) revealed significantly different energy output in demonstration plots than FPP over the years in all the blocks. In 2019, demonstration plots registered 10.96, 10.60, 10.48 and 10.66 % higher energy output in Moga I (15266.25 MJ ha^{-1}), Moga II (15142.50 MJ ha^{-1}), Baghapurana (15176.25 MJ ha^{-1}) and Nihal Singh Wala (15187.50 MJ ha^{-1}), respectively, than FPP. The enhancement in energy output in demonstration plots over FPP can be due to increased seed yield (Table 4) of summer greengram. Any technology or practice which increases realization of economic produce

Table 7: Block wise energy input and output of demonstration and FPP plots in district Moga

Energy Input (MJ ha^{-1})								
Treatment	2017				2019			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	5967	6048	6019	6002	5813	6006	5927	5892
FLD	4823	4987	4961	4902	4781	5962	4806	4792
p=0.05	< .00001	< .00001	< .00001	< .00001	< .00001	0.39343	< .00001	< .00001
SEd	123.3842	125.7305	114.3169	120.2152	106.9534	24.50488	120.3476	118.4419

Treatment	2021			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	5991	6103	6047	6029
FLD	4807	5031	4928	4903
p=0.05	< .00001	< .00001	< .00001	< .00001
SEd	127.3155	116.1637	120.9539	122.7753

Table 7: Continue...

Energy Output (MJ ha^{-1})								
Treatment	2017				2019			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	13173.75	12948.75	13095.00	13117.50	13758.75	13691.25	13736.25	13725.00
FLD	14366.25	14096.25	14197.50	14287.50	15266.25	15142.50	15176.25	15187.50
p=0.05	0.00021	0.000366	0.000621	.000116	< .00001	0.000021	< .00001	< .00001
SEd	174.7993	176.9543	175.0207	170.9264	201.1131	199.1361	192.3602	194.3837

Treatment	2021			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	11880.00	11722.50	11801.25	11846.25
FLD	12723.75	12600.00	12622.50	12656.25
p=0.05	0.003876	0.005219	0.006072	0.012431
SEd	152.5509	162.9831	154.7626	146.4756

of summer greengram results in enhancement in energy output. It can be said that adoption of integrated pest management, judicious use of fertilizers, herbicides and other growth factors creates better avenues for having energy efficient sustainable production systems. Therefore, better energy output with lesser energy requirements in demonstration plots of summer greengram in all the blocks over the years clearly depicts ecological viability of summer greengram cultivation by following technically sound recommendations such as integrated nutrient and pest management.

3.4.2. Energy use efficiency and energy productivity

Analysis of data (Table 8) revealed that demonstration plots registered significantly higher energy use efficiency over the years relative to FPP. For instance, in 2021, demonstration plots recorded 33.84, 30.21, 31.28 and 31.63% higher and significantly higher energy use efficiency in Moga I (2.65), Moga II (2.50), Baghapurana (2.56) and Nihal Singh Wala (2.58), respectively, than FPP, during all the years. Moga I block had highest energy use efficiency in demonstration plots as compared to other three blocks in 2017 (2.98), 2019 (2.19) and 2021 (2.65). High energy use efficiency of demonstration plots can be attributed to low energy requirement, high seed yield and energy output. It further depicts the economic importance of cultivation of summer greengram following the improved cultivars and production technologies which improvise growth, development, seed yield and

Table 8: Block wise energy use efficiency and energy productivity of demonstration and FPP plots in district Moga

Energy use efficiency								
Treatment	2017				2019			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	2.21	2.14	2.18	2.19	2.37	2.28	2.32	2.33
FLD	2.98	2.83	2.86	2.91	3.19	2.54	3.16	3.17
p=0.05	0.4236	0.4323	0.4356	0.4542	< .00001	0.099392	< .00001	< .00001
SEd	0.08823	0.090064	0.090725	0.094627	0.104456	0.076098	0.109765	0.11

Treatment	2021			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	1.98	1.92	1.95	1.96
FLD	2.65	2.50	2.56	2.58
p=0.05	0.000847	0.001271	0.000611	0.000618
SEd	0.10791	0.095373	0.097186	0.098827

Table 8: Continue...

Energy productivity (kg MJ^{-1})								
Treatment	2017				2019			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	0.20	0.19	0.19	0.19	0.21	0.20	0.21	0.21
FLD	0.26	0.25	0.25	0.26	0.28	0.23	0.28	0.28
p=0.05	0.001811	0.001376	0.001035	0.001672	0.008789	0.428267	0.049954	0.034569
SEd	0.010362	0.010021	0.009829	0.011834	0.01371	0.014712	0.015352	0.01435

Treatment	2021			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	0.18	0.17	0.17	0.17
FLD	0.24	0.22	0.23	0.23
p=0.05	0.000157	0.0085	0.00966	0.007794
SEd	0.009424	0.009574	0.011684	0.011429

yield attributes at lesser energy requirements. Energy productivity shows the ability of any production system to produce high economic product per unit of energy used. Data on energy productivity (Table 8) depicted significant difference among demonstration plots and FPP in all the blocks over the years. for example, in 2019, demonstration plots in Moga I, Moga II, Baghapurana and Nihal Singh Wala blocks registered 33.33 (0.28 kgMJ^{-1}), 15.00 (0.23 kg MJ^{-1}), 33.33 (0.28 kg MJ^{-1}) and 33.33 % (0.28 kg MJ^{-1}) higher and significantly different energy productivity, respectively, than FPP. Realisation of seed yield as well as amount of energy required to have that productivity level have direct effect on energy productivity of any production system. The demonstration plots in all the blocks recorded significantly higher seed yield by consuming significantly lesser energy levels, therefore, high energy productivity in demonstration plots can be attributed to enhanced seed yield and lesser energy requirements than FPP over the years.

3.4.3. Net energy and energy profitability

Data on net energy (Table 9) revealed significantly higher net energy in demonstration plots in all the blocks in 2017, 2019 and 2021. For example, in 2021, Moga I (7916.75 MJ ha^{-1}), Moga II (7569.00 MJ ha^{-1}), Baghapurana (7694.50 MJ ha^{-1}) and Nihal Singh Wala (7753.25 MJ ha^{-1}) reported 34.43, 34.69, 33.72 and 33.28 % higher and significantly different net energy in demonstration plots than FPP, respectively. Furthermore, in 2017, 2019 and

Table 9: Block wise net energy and energy profitability of demonstration and FPP plots in district Moga

Net energy (MJ ha^{-1})								
Treatment	2017				2019			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	7206.75	6900.75	7076.00	7115.50	7945.75	7685.25	7809.25	7833
FLD	9543.25	9109.25	9236.5	9385.5	10485.25	9180.5	10370.25	10395.5
p=0.05	< .00001	< .00001	< .00001	< .00001	< .00001	< .00001	< .00001	< .00001
SEd	253.4947	261.9787	236.1599	245.0896	285.2665	182.6141	288.4115	282.8124

Treatment	2021			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	5889.00	5619.50	5754.25	5817.25
FLD	7916.75	7569.00	7694.50	7753.25
p=0.05	< .00001	< .00001	< .00001	< .00001
SEd	248.8465	234.6525	231.0938	222.9318

Table 9: Continue...

Treatment	Energy profitability							
	2017				2019			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	1.21	1.14	1.18	1.19	1.37	1.28	1.32	1.33
FLD	1.98	1.83	1.86	1.91	2.19	1.54	2.16	2.17
p=0.05	0.00002	0.000448	0.000218	0.000115	0.000495	0.020699	0.000015	0.000023
SEd	0.10629	0.107974	0.101898	0.104222	0.12823	0.057996	0.113284	0.114776

Treatment	2021			
	Moga I	Moga II	Baghapurana	Nihal Singh Wala
FPP	0.98	0.92	0.95	0.96
FLD	1.65	1.50	1.56	1.58
p=0.05	0.002165	0.000316	0.000295	0.000246
SEd	0.114435	0.088337	0.092196	0.092751

2021, Moga block recorded highest net energy than rest of the blocks. Any production technology that increases the economic output, energy output per unit of energy use directly enhances the net energy. In view of this, the increase in net energy in demonstration plot in comparison to FPP can be attributed to high seed yield, high energy output and significantly less energy input in all the blocks over the years. similar results were observed in case of energy profitability (Table 9), where demonstration plots recorded significantly higher energy profitability in all the blocks during 2017, 2019 as well as 2021. For instance, Moga I block reported 63.63, 59.85 and 79.35% higher and significantly different energy profitability in 2017 (1.98), 2019 (2.19) and 2021 (1.65), respectively than farmers' practice. Furthermore, Moga I block had highest energy profitability than rest of the blocks in 2017, 2019 and 2021. Increase in energy profitability in demonstrations plots in all the blocks over the years can be due to increase in seed yield (Table 4), energy output (Table 7), net energy (Table 9) and low requirement of energy (Table 7) to have desired productivity level.

4. CONCLUSION

The results, of the frontline demonstrations clearly showed positive effect of improved production technology on grain yield as well as economic viability of summer greengram in all the blocks of the district over the years. From the results it can also be concluded that the adoption of need based nutrient and crop management practices significantly decreases energy requirement, improvises the energy output which in turn makes summer greengram cultivation more energy efficient than local practices.

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