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Research Paper

Quantification and bridging of yield gaps for major crops of Ganderbal district of Jammu and Kashmir

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ABSTRACT

Large gaps exist between the demonstration yield and the yield of a crop under farmers practice. Frontline demonstrations were conducted to evaluate and bridge the yield gaps. In total 506 FLDs were conducted on an area of 176 ha during the last five years (2015-19) on 8 major crops of the region viz., rice, maize, brown sarson, oats, rajmash, cowpea, moong and field pea. The average demonstration yield of all the crops was significantly higher than average check yield ($p<0.05$). For rice, maize, brown sarson, oats, rajmash, cowpea, moong and field pea, the yield of demonstration plots was 37, 58, 39, 55, 48, 30, 23 and 36% higher than the average check yield, respectively. Technological yield gap was maximum in maize var. SMC-4 (41%) and minimum in rice var. SR-2 (2%). Extension yield gap was maximum in maize var. SMC-7 (41%) and minimum for moong (19%). The maximum Technological Index was calculated for maize var. SMC-4 (29.3%) and minimum for rice var. SR-3 (2.0%). Yield gaps and poor economics indicate poor dissemination and adoption of scientific crop management practices by farmers. A more focussed approach is needed to bridge the yield gaps and to improve the farm productivity.

Key words: Attainable yield, demonstration yield, economics, farmers yield, yield gaps

The 21st century is regarded as an era of technological revolution, however the advances in agriculture in the form of improved agronomic practices, quality seed, improved varieties, plant protection technologies, farm machinery and analytics etc., have not downpoured much to farmers' level. In India, 51% of the workforce is employed in agriculture (GoI, 2019), but the farmers are still practising the age old practices with low inputs and low yields. Several factors are considered responsible for low yields and low monetary economics including non-adoption of the recommended package of practices by the farmers, edaphic and climatic factors and several biotic (Ahanger *et al*., 2008) and abiotic stresses (Kumari *et al*., 2014; Dar *et al*., 2017a). Achieving an increase in food production without further exploiting the natural ecosystems will require rise in yield potential and grain yields by devising appropriate management practices to close the existing yield gaps (Meng *et al*., 2013). Closing the existing gaps among potential yield/demonstration yield and the farmers yield is necessary for sustainability in agriculture, as increasing the yield potential through genetic improvement in a short time is a cumbersome activity (Tollenaar and Lee, 2002). The assessment of potential yield and yield gaps for particular crops and cropping systems help identify limiting factors and develop an essential framework within which to prioritize research and policy efforts to reduce these gaps (Abeledo *et al*., 2008). Crop yield gaps have been extensively evaluated worldwide during the recent years (Ahrens *et al*., 2010; Licker *et al*., 2010; Neumann *et al*., 2010), although mainly in cereal food grains but assessments are also available for other crops viz., sunflower (Hall *et al*., 2013), cassava (Fermont *et al*., 2009), pulses (Kumar *et al*., 2017). The yield gaps may vary between 45-100% (Fischer and Edmeades, 2010) or 100-200% (Lobell *et al*., 2009), depending on the crop, region and the level of scientific crop management. The understanding of these yield gaps is critical to understand the bottlenecks in the food production of the region and to recognise the target crops or practices that need to be focussed. Further economic analysis of the different crops of the region is important to understand the profitability of growing different crops and the level of input use as influenced by the economics of the crop. In this background, this study was conducted with the following objectives: (1) to study the attainable and the farmers yield, (2) to analyse the yield gap and management options and (3) to study the economics of 8 major crops of the region viz., rice, maize, Brown sarson, oats, rajmash, cowpea, moong and field pea grown under frontline demonstrations and farmers management over a period of 3-5 years (2015-19).

MATERIALS AND METHODS

Site description: The study was taken over a period of 3-5 years by Krishi Vigyan Kendra, Ganderbal (34° 11′ N, 74° 49′ E, elevation 1605 metres amsl)), Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India in the Ganderbal district of Jammu and Kashmir North-western Himalayan region of India on 8 major crops of the region viz., rice (Oryza sativa L.), maize (Zea Mays L.), Brown sarson (Brassica Juncea L.), Oats (Avena sativa L.), rajmash (Phaseolus vulgaris L.), cowpea (Vigna unguiculata L.), Moong (Vigna radiata L.) and field pea (Pisum sativum L.). The soils of the experimental sites were medium in N [(337-455 kg ha^{-1}), P (15-21 kg ha^{-1}) and K (125-190 kg ha^{-1})] status. The texture of the soil was sandy, clay loam and silty loam for different soil samples of frontline demonstrations (Table 1).

Table 1. Soil properties of the demonstration plots averaged across locations

N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Texture
382.5 (337-455)	18.2 (15-21)	162.4 (125-190)	Sandy, clay loam, silty loam

A study was taken in the form of "Front Line Demonstrations" in different regions (Nuner, Bakura, Basurbugh, Shuhama, Warpora, Ussan, Watlar, Rabitar, Khalmulla, Hariganwan, Dardwuder, Gutllibagh, Repora, Beehama, Lar, Surfraw, Mammer) of district Ganderbal of J&K. {A Front Line demonstration is the horizontal expansion of a tested technology under local agro-climatic conditions. The technology is initially evaluated under "On Farm Testing" which is testing of a university recommended practice under local agro-climatic conditions on a small scale. If a technology performs well under On Farm Testing (OFT) and is validated, then only it is considered for Front Line Demonstrations (FLDs) on a large scale}. In the present study, the major differences were found in six technologies viz., variety, seed rate, sowing time, sowing method, fertilizer dose and plant protection/technical guidance (Table 2). The number of FLDs and the area taken for different crops/varieties and their potential yield is given in Table 3.

Table 2. Comparison of the technological components demonstrated under front line demonstrations and those practised by farmers

Crop	Technology component	Demonstration plot	Farmers practice
Rice	Variety	Shalimar rice (SR)-2/4/5	China-1039, Jhelum, Goud wozul
	Seed rate (kg/ha)	60-80 kg	180-200
	Sowing time	Last week of May-1st week of June	Mid May-2nd week of June
	Sowing method	Transplanting	Transplanting
	Fertilizer dose (kg/ha)	Urea: 210, DAP: 130, MOP: 50	Urea: 120-150, DAP: 150 and MOP: 0
	Plant protection	Seed treatment (Mancozeb 75 WP or captan 50 WP @ 3g/kg seed+tricyclozole 25 WP@ 0.6g/kg seed) and need based spray (carbendazim 50 WP @1g/l of water or tricyclazole @0.6g/l of water) for blast, brown spot and sheath blight management	Seed treatment by few farmers (Mancozeb 75 WP or captan 50 WP @ 3g/kg seed) and spray of carbendazim 50 WP @1g/l of water for blast, brown spot and sheath blight management
Maize	Variety	Shalimar Maize Composite (SMC)-4/7	Local, Badi Makai
	Seed rate (kg/ha)	30	50-60
	Sowing time	1st week of April-Last week of April	Last week of March-Mid April
	Sowing method	Line sowing	Broadcasting
	Fertilizer dose (kg/ha)	Urea: 210, DAP:130, MOP: 50, $ZnSO_4$: 15	Urea: 50, DAP: 40 and MOP: 0
	Plant protection	Seed treatment (Mancozeb 75 WP or captan 50 WP @ 3g/kg seed) and need based spray (chloropyriphos @1m/l of water)	NIL

Table 2 continued

Crop	Technology component	Demonstration plot	Farmers practice
Brown Sarson	Variety	KS-101/Shalimar Sarson (SS)-2	Local
	Seed rate (kg/ha)	8-10	15-20
	Sowing time	1st fortnight of October	1st fortnight of October-1st fortnight of November
	Sowing method	Line sowing	Broadcasting
	Fertilizer dose (kg/ha)	Urea : 132, DAP: 110, MOP: 68, Gypsum: 130	Urea: 40, DAP: 60 and MOP: 0
	Plant protection	Need based (Dimethoate 30 EC@)1 ml/l of water)	NIL
Oats	Variety	Shalimar Fodder Oats (SFO) 2/3	Local
	Seed rate (kg/ha)	100	250
	Sowing time	Mid-September-Mid October	End September-End November
	Sowing method	Line sowing	Broadcasting
	Fertilizer dose (kg/ha)	Urea: 276, DAP:130, MOP: 67	Urea: 150, DAP: 100 and MOP: 0
	Plant protection	Need based	NIL
Rajmash	Variety	Shalimar Rajmash (SRaj)-1/2	Local
	Seed rate (kg/ha)	60-70	120
	Sowing time	Mid April-1st week of May	End March-End May
	Sowing method	Line sowing	Broadcasting
	Fertilizer dose (kg/ha)	Urea:15, DAP:130 and MOP:50	Urea: 50, DAP: 50 and MOP: 0
	Plant protection	Need based spray of carbendazin 50 WP @0.1% or carbendazim+Mancozeb 75 WP@0.25% for control of Anthracnose/White mold	NIL
Cowpea	Variety	Shalimar Cowpea (SC)-1	Local
	Seed rate (kg/ha)	40	60
	Sowing time	Last week of April-Mid May	End March-End May
	Sowing method	Line sowing	Broadcasting
	Fertilizer dose (kg/ha)	Urea:15, DAP:130 and MOP:50	Urea: 50, DAP: 40 and MOP: 0
	Plant protection	Need based spray of carbendazin 50 WP @0.1% or carbendazim+Mancozeb 75 WP@0.25% for control of Fusarium wilt/Cercospora leaf spot	NIL
Moong	Variety	Shalimar Moong (SM)-1/2	Local
	Seed rate (kg/ha)	25	40
	Sowing time	Mid May-End May	End March-End May
	Sowing method	Line sowing	Broadcasting
	Fertilizer dose (kg/ha)	Urea:15, DAP:130 and MOP:50	Urea: 50, DAP: 40 and MOP: 0
	Plant protection	Need based spray of carbendazin 50 WP @0.1% or carbendazim+Mancozeb 75 WP@0.25% for control of Fusarium wilt/Cercospora leaf spot	NIL
Field Pea	Variety	Shalimar Field Pea (SFP)-1	Local
	Seed rate (kg/ha)	60-65	100
	Sowing time	Mid October-End November	End October-End November
	Sowing method	Line sowing	Broadcasting
	Fertilizer dose (kg/ha)	Urea:15, DAP:130 and MOP:50	Urea: 40, DAP:80 and MOP:0
	Plant protection/Seed treatment	Inoculation with Rhizobium and PSB. Need based spray of carbendazin 50 WP @0.1% or carbendazim+Mancozeb 75 WP@0.25% for control of white rot/Ascochyta blight.	NIL

Details of Crop and technological components: Six technological components viz., variety, seed rate, sowing time, sowing method, fertilizer dose, plant protection/technical guidance were studied for eight major crops of the region (Table 2).

Table 3. Details of Front Line demonstrations and the potential yield of different varieties of eight major crops of the region.

Crop	Variety	No. of FLDs	Area (ha)	Potential yield (kg ha^{-1})
Rice	SR-2	24	6.4	8000
	SR-3	29	9.0	7500
	SR-4	80	51.5	9000
	SR-5	28	6.75	5500
Maize	SMC-4	24	7.0	5800
	SMC-7	17	4.5	6500
Brown Sarson	KS-101/SS-2	45	20	1400
Oats	SFO-2/3	80	10.0	40000
Rajmash	SRaj1/2	65	20.0	1200
Cowpea	SC-1	60	20.0	850
Moong	SM-1/2	31	11.0	1000
Pea	SFP-1	23	10.0	1400

Calculation of yield and technological yield index

Average demonstration yield (ADY)/attainable yield is the average yield of all the front line demonstrations taken for a particular crop across different locations. Average check yield (ACY)/farmers yield is the average yield of a crop under farmers practice across different locations. "Yield potential/potential yield (PY) is defined as the yield of a crop variety or hybrid when grown in environments to which it is adapted and with pests and diseases effectively controlled. Farmers yield is defined as the actual yield of a crop under farmers' management. "Attainable yield or demonstration yield is defined as the maximum yield recorded in a given agro-ecological zone using locally optimised agricultural best practices and adapted current crop cultivars". Yield gap is generally calculated as the difference between the potential yield and the actual farmers yield, described in this paper as yield gap-III. However, for practical purposes, yield gap is calculated as the difference in attainable yield and the farmers yield, described in this paper as extension yield gap (EYG)/Yield gap-I. It is alternatively, calculated as the difference in potential yield and the attainable yield described in this paper as technology yield gap (TYG)/Yield gap-II. Technological yield gap (TYG), extension yield gap (EYG) and technological index (TI) are calculated to see the impact of a technology under farming situations. The calculations were done as follows (Hall *et al*., 2013; Kumar *et al*., 2017).

$$\text{ADY (kg/ha)} = \sum_{n=1}^{n} \frac{\text{Ydi}}{\text{ni}} \quad \text{...Eq.1}$$

Where, ADY, is the average demonstration yield, Ydi, is yield in ith demonstration plot

$$\text{ACY (kg/ha)} = \sum_{n=1}^{n} \frac{\text{Yci}}{\text{ni}} \quad \text{...Eq. 2}$$

Where, ACY, is the average check yield, Yci, is yield in ith check plot

$$\text{Percentage yield increase over check (\%)} = \frac{\text{ADY}\left(\frac{\text{kg}}{\text{ha}}\right) - \text{ACY}\left(\frac{\text{kg}}{\text{ha}}\right)}{\text{ACY}\left(\frac{\text{kg}}{\text{ha}}\right)} \times 100 \quad \text{...Eq.3}$$

Where, ADY, is the average demonstration yield, ACY, is the average check yield

$$\text{TYG (kg/ha)} = \text{PY (kg/ha)} - \text{ADY(kg/ha)} \quad \text{...Eq.4}$$

Where, TYG, is the technological yield gap, PY, is the potential yield and ADY, is the average demonstration yield

$$\text{EYG (kg/ha)} = \text{ADY(kg/ha)} - \text{ACY (kg/ha)} \quad \text{...Eq.5}$$

Where, EYG, is the extension yield gap, ADY, is the average demonstration yield and ACY, is the average check yield

$$\text{TI (\%)} = \frac{\text{PY (kg/ha)} - \text{ADY(kg/ha)}}{\text{PY(kg/ha)}} \times 100 \quad \text{...Eq.6}$$

Where, TI, is the mean technological index, PY, is the potential yield and ADY, is the average demonstration yield

Economics*:* Prevailing market rate of inputs was used to calculate the cost of cultivation, gross and net returns and averaged across years.

Statistical analysis: The average demonstration yield and average check yield were computed. T-test was used to compare the yield and economics of demonstration and farmers practices using ~~Proc GLM procedure of~~ SAS version 9.4 (SAS Institute, Inc., Cary, NC, USA). The differences were considered significant at $p<0.05$

RESULTS AND DISCUSSION

Yield and yield gaps: The average demonstration yield of all the crops was significantly higher than average check yield ($p<0.05$). For rice (var. SR-2, SR-3, SR-4, SR-5) the percentage yield increase in demonstration plots over check was 32, 39, 40 and 35% respectively (Fig. 1). For maize, the average demonstration yield with SMC-4 and SMC-7 variety was 46 and 70% higher as compared to the check plots, respectively. For brown sarson the average demonstration yield was 39% higher than the average check yield. Similarly for other crops like oats, rajmash, cowpea, moong and field pea, the average demonstration yield was 55, 48, 30, 23 and 36% higher than the average check yield, respectively. The difference in yield at different locations may be due to the variations in the micro-climatic and edaphic conditions of the area or the level of management adopted (Dar *et al*., 2017b).

The data presented in Table 4, revealed the average maximum EYG (yield gap-I) of 12700 (ranging from 12630-12753) kg ha^{-1} in oats, followed by 2200 kg ha^{-1} in rice var. SR-4. The minimum EYG was observed for moong (179 kg ha^{-1}), followed by cowpea (180 kg ha^{-1}). The technological yield gap, TYG (yield gap-II) was maximum in oats (4300 kg ha^{-1}), followed by rice var. SR-4 (1300 kg ha^{-1}). The minimum TYG was observed in cowpea (40 kg ha^{-1}), followed by moong (50 kg ha^{-1}). The maximum YG-III was recorded for oats (17000 kg ha^{-1}), followed by maize var. SMC-7 (3500 kg ha^{-1}) and rice var. SR-4 (3500 kg ha^{-1}). The minimum gap was recorded in cowpea (220 kg ha^{-1}), followed by moong (230 kg ha^{-1}). There was a large difference between the minimum and the maximum yield gaps of all the crops. The yield gap-I (YG-1) was much lower than the yield gap-II (YG-11) and III (YG-III) viz., for oats, the difference was 123 kg ha^{-1} for YG-I, while it was 6925 and 7000 kg ha^{-1} for YG-II and YG-III, respectively. In spite of the intensification of management, the potential yield was higher than attainable yield by 2-40% (Table 3). However, it is necessary to note that such yield levels may not be profitable owing to the requirement of much higher management intensity. Most studies have concluded that 80% of the soil and climate defined potential yield is a good approximation for economically attainable potential yield (Van Rees et al., 2014; Van Ittersum *et al*., 2013). So, such yield gaps exist but accurate computation and devising management practices to close or reduce these yield gaps becomes necessary for higher productivity. Yield gaps have been calculated in different ways by different researchers. However, in this paper we have calculated it in the three best ways as referenced in the literature, as Yield gap-I, II and III. Yield gap-I, named as Extension yield gap (EYG) depicts the difference in attainable (demonstration) yield and the check yield. The data presented in Table 4 and Fig. 2, revealed the maximum EYG of 41% in SMC-7 variety of maize, followed by 30% in rajmash. The minimum EYG was observed for moong (19%), followed by SR-2 variety of rice (24%). Yield gap-II, named as Technological yield gap (TYG), depicts the difference in potential yield and the demonstration yield and thus reveals the gap in technology between the research and the farm scientists. Data presented in Fig. 2 revealed that the percentage technological yield gap was maximum in SMC-4 variety of maize (41%), followed by field pea (37%). The minimum percentage TYG was observed in SR-2 variety of rice (2%), followed by SR-5 variety of rice, cowpea and moong (5%). On an average, TYG was lower for pulses (15%) as compared to cereals (19%). The TYG was higher (20%) as compared to the EYG (26%), revealing the fact that yields are much lower in check plots as compared to the demonstration plots.

Dissemination of scientific management practices and their adoption by the farmers is thus seriously needed to fill the gap and to increase the overall food production. Yield gap-III (YG-III), depicts the difference between potential yield and the farmers yield. The maximum YG-III was recorded for oats and minimum gap was recorded in cowpea. However, as percentage of the attainable yield, the YG-III ranged from 24-73%, with minimum in moong and maximum in maize var. SMC-4. Overall, it was much higher (46%) than the EYG (26%) and TYG (20%). However, the fact is that the potential yield cannot be achieved at the farmers' field even with maximum intensification of technologies, due to the prevailing climatic, edaphic and management constraints. Therefore, management options should aim for closing gaps at a lower level of 75-85% of potential yield (Van Ittersum *et al*., 2013). On percentage basis, several other researchers have reported yield gaps of 45-100% (Fischer and Edmeades 2010) or 100-200% (Lobell *et al*., 2009). In absolute terms, yield gaps of >4 ton were recorded in maize (Devkota *et al*., 2015), 4.5 ton in rice (Meng *et al*., 2013), 1.3 ton in chickpea and 1.2 ton in moong (Kumar *et al*., 2017). An analysis and understanding of the yield gaps helps to devise management options for improving the productivity of crops and to develop research and market policies for different crops (Abeledo *et al*., 2008; Ahrens *et al*., 2010; Licker *et al*., 2010; Neumann *et al*., 2010).

Table 4. Descriptive statistics for the three yield gaps of eight major crops

Yield gap	Variety	Min	Max	Mean	Q1	Q3
Yield Gap-I	SR-2	1637	1662	1650	1643	1656
	SR-3	2035	2061	2050	2041	2061
	SR-4	2185	2213	2201	2193	2213
	SR-5	1340	1359	1350	1345	1355
	SMC-4	1293	1306	1301	1298	1306
	SMC-7	2091	2106	2100	2097	2106
	KS-101/SS-2	299	302	301	300	302
	SFO-2/3	12630	12753	12700	12670	12753
	SRaj1/2	328	331	330	329	331
	SC-1	179	181	180	180	181
	SM-1/2	178	181	180	179	181
	SFP-1	268	271	270	270	271
Yield Gap-II	SR-2	2553	3212	2900	2862	2934
	SR-3	2060	2411	2200	2141	2216
	SR-4	2940	3983	3500	3404	3585
	SR-5	1417	1933	1600	1520	1639
	SMC-4	2706	3214	3001	2944	3084
	SMC-7	3247	3786	3500	3317	3651
	KS-101/SS-2	481	752	621	550	692
	SFO-2/3	14053	20978	17000	15742	17877
	SRaj1/2	380	521	450	423	477
	SC-1	184	321	220	200	233
	SM-1/2	206	291	230	215	236
	SFP-1	565	725	650	616	683
Yield Gap-III	SR-2	900	1550	1250	1200	1281
	SR-3	20	350	150	100	180
	SR-4	750	1779	1300	1200	1385
	SR-5	70	580	250	168	295
	SMC-4	1400	1920	1700	1643	1790
	SMC-7	1150	1680	1400	1211	1550
	KS-101	180	450	320	250	390
	SFO-2/3	1300	8300	4300	3010	5176
	SRaj1/2	50	190	120	93	146
	SC-1	5	140	40	20	52
	SM-1/2	25	110	50	35	56
	SFP-1	295	455	380	345	413

Technological index (%): Data presented in Fig. 1 revealed that maximum TI was recorded for maize var. SMC-4 (29.3%), followed by 27.1% in field pea. Lowest TI was recorded for rice var. SR-3 (2.0%), followed by cowpea (4.4%) and rice var. SR-5 (4.5%). Overall, the TI was lower for pulses (11%) than cereals (14%). TI is a valuable tool to determine the impact of technologies on farmer's field. It shows the feasibility of generated farm technologies on the farmer's fields under prevailing agro climatic situations. Lower the TI, higher is the feasibility of generated farm technology on farmer's fields and vice-versa. Data presented in Fig. 1, revealed that TI varied from 4.4% to 29.3% for different crops. The mean TI was higher for cereals (rice and maize) than pulses (rajmash, cowpea, moong and field pea). On crop basis, the maximum and minimum TI was calculated for maize and rice, respectively. Higher TI in brown sarson (23%) shows the low feasibility of existing technologies of oilseed cultivation on farmer's field. The mean TI was 14% for the different crops, revealing a need for sufficient refinement of the existing crop production technologies. Similarly, Kumar *et al.* (2017) evaluated TI for different crops and reported a range of 6-86%. The study inferred that dissemination of technologies, infrastructure development, capacity building of farmers and generation of feasible technologies through on farm testing and front line demonstration may lead to higher productivity and improve the technological index of different crops in the region, as also reported by Vedna *et al*., (2007); Choudhary *et al*., (2009).

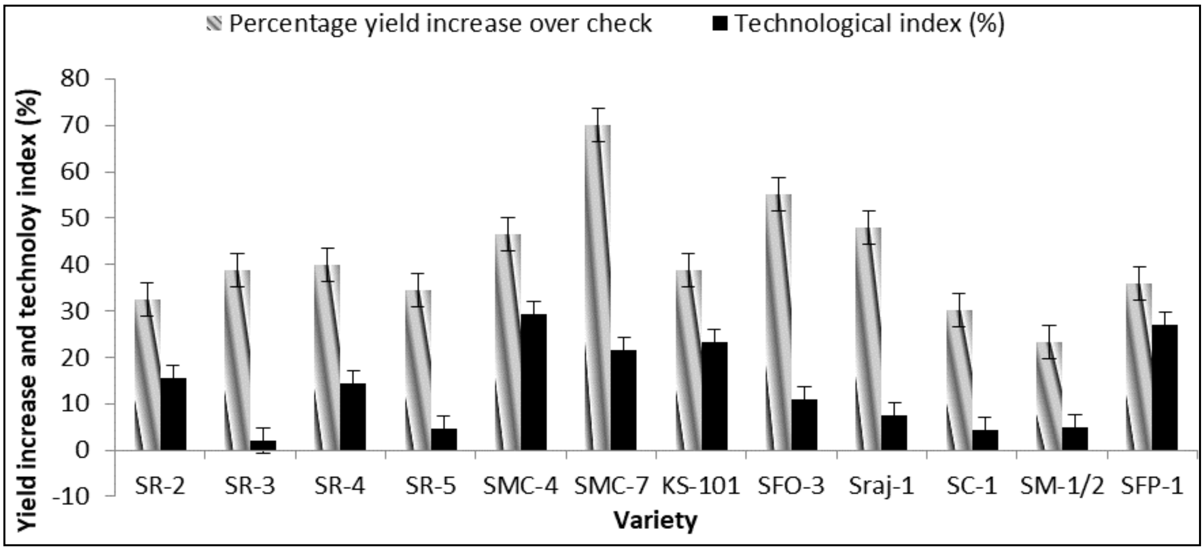

Fig.1: Yield increase over farmer's practice and technology index. Bars represent the mean values (±SE)

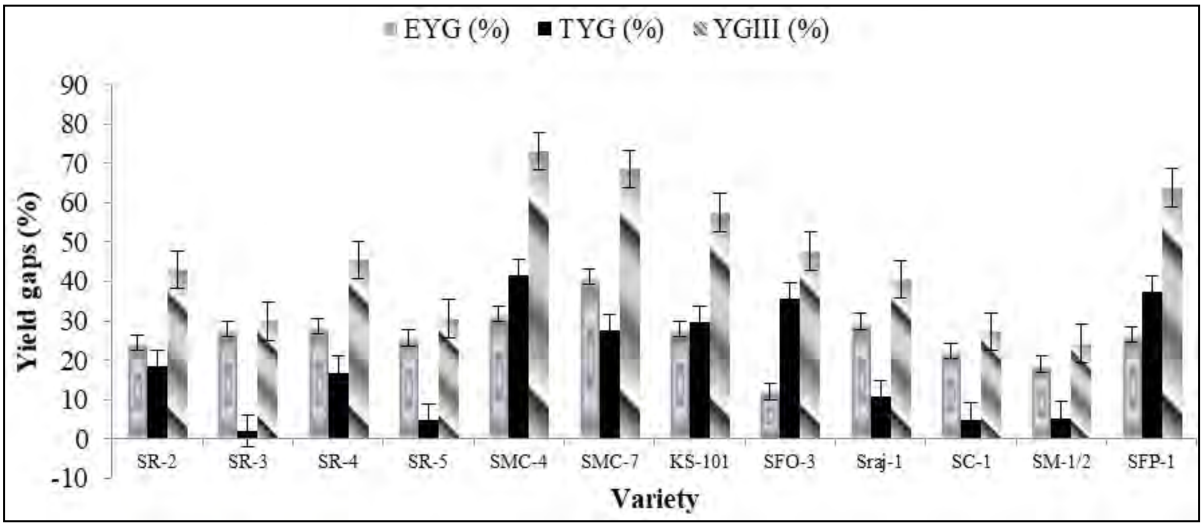

Fig. 2: Extension yield gap, technology index and yield gap-III. Bars represent the mean values. All the three mean values (±SE) of gaps for a particular variety were statistically different at p<0.05

Economics: The data presented in Fig. 3, revealed that the highest cost of cultivation of demonstration plots was recorded for rice (INR 66550 ha^{-1}). In the check plots, the cost of cultivation was also highest for rice (INR 57475 ha^{-1}). The lowest cost of cultivation was calculated for field pea (INR 18500 ha^{-1}). Following the trend, the gross returns for demonstration plots and check plots were highest in rice (INR 191200 and INR 151775 ha^{-1}) and lowest in brown sarson (INR 53750 and INR 38750 ha^{-1}). Similarly net returns were highest in rice demonstration plot (INR 124650 ha^{-1}) and lowest for brown sarson (INR 28750). The economics of crop production provides the real monetary benefits of technology adoption. The average cost of cultivation (in Indian rupees, henceforth as INR) was higher for demonstration plots as compared to check plots (Fig. 3). The highest cost of cultivation of demonstration plots as well as with farmers practice was calculated for rice. In contrast, it was lowest for field pea, followed by oats. The cost of cultivation was lower for pulses as compared to cereals, because the farmers invest least in pulse cultivation, which may be attributed to their low yields, low market stability and higher risk to abiotic stresses, particularly water stress. Rice is the main crop other than apple, where farmers invest their money. Following the trend, the gross returns for demonstration plots and check plots were highest in rice and lowest in brown sarson. Among pulses, the gross returns (INR 162400 and 121075 ha^{-1}) in demonstration plots and check plots, respectively, were highest in moong than other pulse crops. Similarly net returns were highest in rice, followed by moong and lowest for brown sarson (INR 28750 and 16250 ha^{-1}). An important index of evaluating the net income earned per rupee invested is the benefit cost ratio (B:C). All the demonstration plots were having higher B:C than the check plots. The highest B:C in demonstration and check plots , respectively, was recorded for moong (4.54 and 2.88), followed by oats (2.74 and 1.92), while, the lowest B:C was recorded for brown sarson (1.15 and 0.72), followed by rice var. SR-5 (1.52 and 1.45). On an average, the B:C was higher for pulses (2.79 and 1.74) than that of the other crops (1.93 and 1.50), revealing higher benefits in pulses, per rupee invested as compared to other crops. The inference that can be drawn is that the gross and net returns in rice are higher because of higher yields, while it is higher in moong because of higher market price. The benefit cost ratio is higher in pulses because of higher net returns in comparison to the cost of cultivation incurred. However use of limited inputs in pulses and cultivation under rainfed conditions are responsible for the low yield of pulses and thereby low gross and net returns. Dissemination, adoption and intensification of scientific technologies are needed to reduce the costs and improve the gross and net returns of a crop and to make the pulse farming economically viable. An increase in monetary returns and benefit cost ratio through technological interventions was also reported by Sagar (2004); Devkota *et al*. (2015).

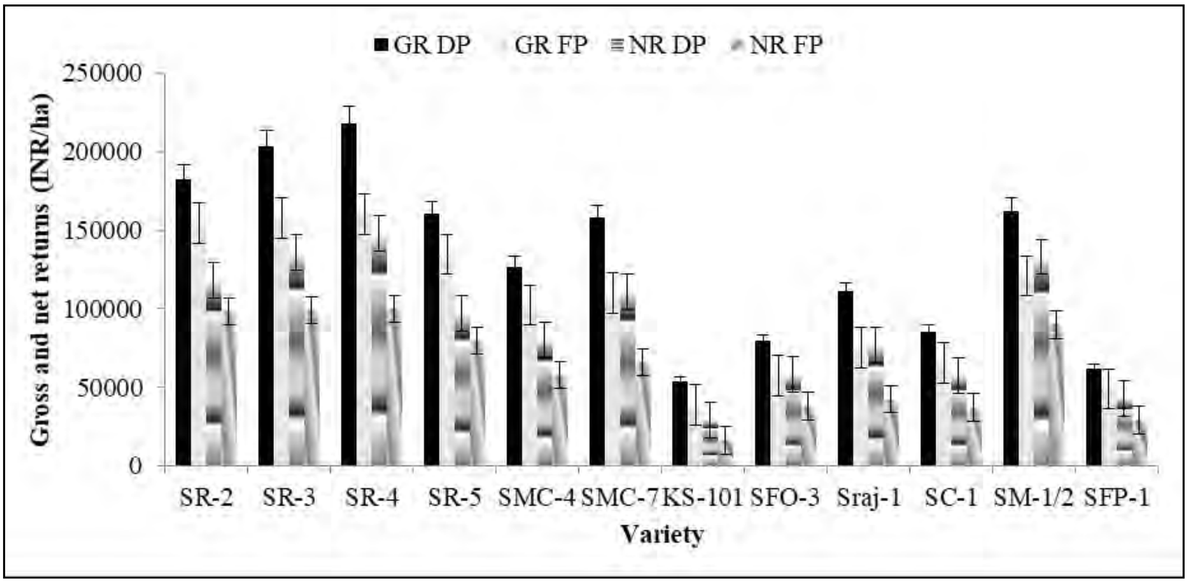

Fig. 3: Gross returns (GR) and Net returns (NR) in demonstration plot (DP) and farmers practice (FP). Bars represent the mean values (±SE). All the four mean values for a particular variety were statistically different at $p<0.05$

CONCLUSION

In spite of the development in agricultural sector and generation of technologies for better management of crop, the adoption of technologies by farmers is least. Poor technical knowhow of the farmers is responsible for poor crop management and low productivity. The yield under demonstration plots (DP) was much higher than the farmer's practices. The percentage yield increase in DP over check was more than 30% in all the crops. Technological and extension yield gaps indicate poor dissemination and adoption of scientific crop management practices. Technological index was more than 10% for most of the crops. A more focussed approach through frontline demonstrations and capacity building of farmers through trainings, method demonstrations, impact assessments and exposure visits is needed to bridge the yield gaps and to improve the farm productivity and farmers income and living standards.

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