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Adoption of Improved Technologies for Cropping Intensification in the Coastal Zone of West Bengal, India: A Village Level Study for Impact Assessment

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This study evaluates the impact of improved agricultural technologies that were introduced in selected areas of coastal West Bengal (India) during 2016-2018 to demonstrate their ability to improve the agricultural, social and economic status of farming communities in the study region. The study employed participatory innovation tree (PIT) exercise followed by a questionnaire survey at Rangabelia and Jatirampur villages under Rangabelia gram panchayat, Gosaba Community Development Block of South 24 Parganas district, West Bengal, India. The demonstrated technologies were: Tech. 1, introduction of post-monsoon relay crop lathyrus in medium-up and medium-lowland by adjusting date of sowing of rice varieties; Tech. 2, water saving options (drip irrigation + straw mulch) in high value post-monsoon crop tomato, and Tech. 3, zero tillage and mulching techniques for different potato cultivars. Eighteen impact indicators (II) were identified by PIT exercises on all three technologies and included in an interview schedule. Analyzed data revealed that amongst the eighteen IIs, better yield (II-8) had the highest sensitivity towards adoption of Tech. 1. Less water requirement (II-2) showed highest sensitivity for the adoption of Tech. 2. Both the above-mentioned indicators were equally sensitive for the adoption of Tech. 3. All three technologies mostly reduced the fertilizer application, increased the system productivity, net return and benefit: cost ratio over farmers' conventional practices. Although all three technologies demonstrated almost equal values of sustainable yield index (SYI), based on lowest standard deviation (σ) of respective yield values, the Tech. 1 could be considered as most sustainable in the study location.

(***Key words:*** *Coastal saline zone, Impact pathway, Sustainable intensification, West Bengal)*

Present-day agricultural development needs addressing the global challenges inclusive of the demand of increased agricultural production by keeping pace with increased population, urbanization, land degradation, and exacerbating consequences of climate change (Mwongera *et al*., 2017). Practical implementation of the concept "sustainable intensification" (SI) at the farmer's field-level can have the appropriate answer to these challenges (Schut *et al*., 2016; Smith *et al*., 2017). The rationale of the concept encompasses objectives like productivity enhancement (introducing new varieties, adoption of integrated crop management practices, etc.), economics (higher profitability, ensuring good market linkages, etc.) and social (gender equity, better technology dissemination, etc.) benefits, and environment friendliness (low energy use, low greenhouse gas emission) of the farming systems (Tittonell, 2014). Any farming system that follows the principles of sustainable intensification can enjoy several benefits that distinguish them from conventional systems. The perceived benefits from sustainably intensified systems can be summarized as, i) these systems are multifunctional taking into consideration the natural resource management and economics parts (Dobbs and Pretty, 2004), ii) they consider marketing facilities apart from merely producing food materials, iii) they take well care of environmental factors such as carbon sequestration, flood protection, groundwater recharge, etc., and iv) these systems, depending on new configurations of social capital, are diverse, synergistic, uncertainty-offsetting and tailored to site-specific social-ecological contexts (Friis-Hansen, 2012).

The study location (*i.e.* Rangabelia and Jatirampur villages under Gosaba block, South 24 Parganas district,

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West Bengal) is mainly predominated by *kharif* rice-fallow system. Saline soil, flash flood, the uncertainty of rainfall, etc. along with aggravated climate change related problems have made the farming activities difficult in the study areas which fall within the periphery of coastal zone of West Bengal (Banerjee *et al*., 2018). The major bottlenecks of this area are lack of irrigation water, cultivation of long-duration varieties of rice (Banerjee *et al*., 2018), soil moisture stress at planting time of winter crops, water-logging and excessive moisture in November/December, lack of appropriate varieties of winter crops for late planting (Banerjee *et al*., 2017). Besides, lack of technological know-how, dissemination of farming skills and market facilities have made the situation worse. Some improved practices have been introduced jointly by Bidhan Chandra Krishi Viswavidyalaya (BCKV) and Australian Centre for International Agricultural Research (ACIAR) during 2016-2018 for the agricultural, social and economic development of the study region. The adopted technologies are: Tech. 1, introducing post-monsoon relay crop lathyrus in medium-up and medium-lowland by adjusting date of sowing of rice varieties; Tech. 2, performing water saving options (drip irrigation + straw mulch) in high value post-monsoon crop tomato and Tech. 3, performing zero tillage and mulching techniques for different potato cultivars. The implementation of sustainable intensification through scientific interference can be a good option for the site-specific solution of the problems in this area.

The objective of impact assessment (IA) within the farmers of any area is to demonstrate that how has any agricultural technology been successfully disseminated among them (Ekboir, 2003). To justify international research investment, these technologies, and the processes by which they were locally constructed, need to be scaled-out and scaled-up so that more farmers can benefit. Presently, such type of evaluation is being increasingly used to characterize an organization that is managed to achieve outcomes and impacts, not just to produce outputs (Smith and Sutherland, 2002). This is because a move to understanding innovation as a complex, non-linear and social process implies a move from on-station research, where researchers develop technologies by themselves, to on-farm research where technologies are developed together with the end-users. Besides, on-farm researches need to be responsive to farmers' perceptions and modifications through good monitoring and evaluation. Conclusively, the information obtained from on-farm research must be utilized by the stakeholders involved.

We took a humble approach to study the impact of such new technologies on the direct and indirect users in the study location. In brief, specific objectives of the present study were to assess a) the impact pathways of the improved technologies and b) the sustainable intensification of the systems after the intervention with selected technologies.

MATERIALS AND METHODS

Study area and sampling procedure

For the present study, two villages were purposively selected from all the villages where technologies were demonstrated (Fig. 1). For the selection of respondents, a modified participatory innovation tree (PIT) exercise (Van Mele and Zakaria, 2002; Goswami and Ali, 2011) was followed for identifying all farmers who

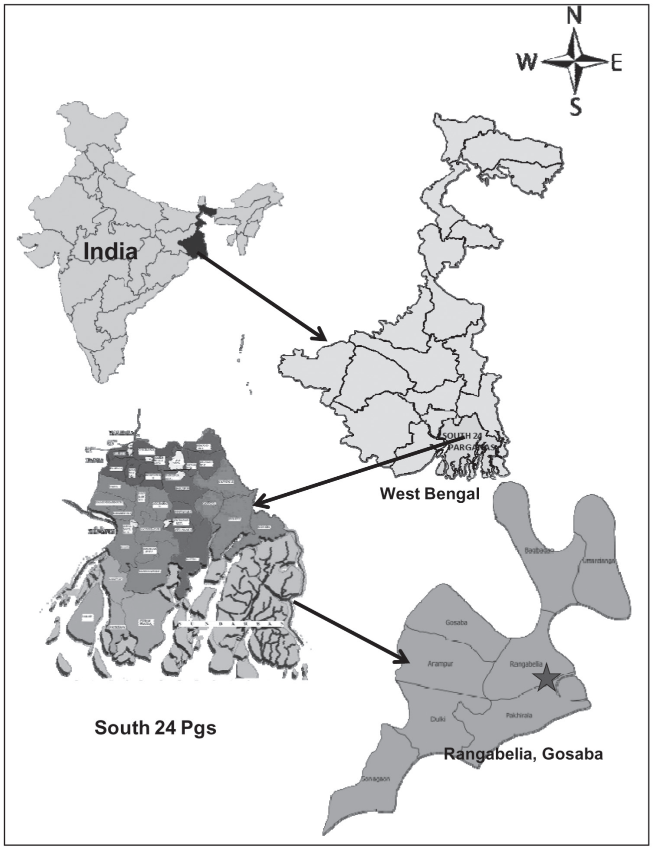

Fig. 1. *Location of the study*

had adopted at least one of the three technologies demonstrated. A total of forty farmers adopting any of these three technologies constituted the sampling frame and enumerated totally in the questionnaire survey.

Indicators of sustainable intensification

Productivity indicator

Sustainable yield index (SYI)

The SYI represents a quantitative measure to assess the sustainability of any agricultural practice (Mozumder *et al*., 2014), and its value varies between zero and unity. The low value of standard deviation (σ) suggests sustainability of the system, while high value of σ indicates unsustainable management practice. The ideal technology is one where σ is zero and mean yield (Y_a) equals to maximum observed yield (Ym), indicating SYI = 1, and this technology gives consistently maximum yield over the years.

$$\text{Sustainable yield index (SYI)} = \frac{(Y_a - \sigma)}{Y_m} \qquad ...(1)$$

where, Y_a = mean system productivity achieved with the technology, σ = standard deviation of system productivity, Y_m = maximum system productivity achieved with the technology.

System productivity

Yield of different crops in the dry season (both winter and summer crops) as informed by farmers were converted into rice equivalent yield (REY) as per the formula given below (Rautaray *et al*., 2017):

$$REY_d \text{ (t ha}^{-1}) = Y_x \, \frac{P_x}{P_r} \qquad ...(2)$$

where, Y_x is the yield of a dry season crops (t ha^{-1}), P_x is the price of the dry season crop (₹ t^{-1}), and P_r is the price of rice (₹ t^{-1}).

Then the system productivity in terms of REY (t ha^{-1}) was calculated by adding the rice yield (t ha^{-1}) in wet season to the REY_d (t ha^{-1}).

Economic indicator

Cost of cultivation for the recommended technologies were calculated as per information provided by the farmers, and it was determined from the cost incurred for performing field operations (from sowing to harvesting, threshing, and storage of seeds) and input used for all crops in a cropping system. Hence, the concept 'Cost A1' as proposed by Commission for Agricultural Costs and Prices (CACP) was followed. Prevailing market price (during 2017-18) of inputs and outputs were estimated in Indian Rupees (₹). Then gross return, net return, and benefit:cost ratio (B:C ratio) were determined using the following formula (Ray *et al*., 2018):

Gross return (₹ ha^{-1}) = System's output (kg ha^{-1}) x Output price (₹ kg^{-1}) …(3)

Net return (₹ ha^{-1}) = Gross return (₹ ha^{-1}) – Cost of cultivation (₹ ha^{-1}) …(4)

Benefit: cost ratio = Gross return/ Cost of cultivation …(5)

Environmental indicator

Reduction of chemical input (fertilizer, pesticide, etc.) in any production system has been considered as an important practice ensuring environmental sustainability (Smith *et al*., 2017). Hence, in the present study, the quantity of chemical fertilizers applied in every system both before and after the adoption of new technologies was determined to make logical conclusions.

Assessment of impact pathway evaluation

Estimation of modified farmer's participatory innovation tree (PIT)

Modified PIT exercise (Van Mele and Zakaria, 2002; Goswami and Ali, 2011) was employed to study the adoption and diffusion of selected technologies (Tech. 1, 2 and 3) among the practicing farmers. Participants were asked to draw the diffusion of technologies among the members of a community over time and mention the associated perceived benefits at every incidence of the spread of a technology (from one farmer to another). Thus, eighteen (18) impact indicators (II) were identified based on farmers' perceived benefits and used as the items in the interview schedule (Table 1).

Scoring the impact indicators

For each technology, all impact indicators were given a score by each respondent, the coding scheme being, 'benefit perceived' = 1, 'else' = 0. Mean score, covering all respondents, for each indicator was scaled uniformly (0-1 range) for meaningful comparison, and finally the mean total impact for each technology was assessed by 0-10 scales.

Data collection

The survey was conducted from November 2017 to May 2018 in two selected villages. The pre-testing of the research design was conducted during April 2017 and data were collected from the respondents through personal interviews using a semi-structured interview schedule.

RESULTS AND DISCUSSION

Modified farmers' participatory innovation tree (PIT)

The PIT describes how the technologies were disseminated among the respondents over time. The pathways of diffusion of Tech. 1, 2 and 3 have been illustrated in Figures 2, 3 and 4, respectively. In each step (two immediately linked farmers) we have given the perceived impact indicators (Table 1) that facilitated the adoption of a given technology. These indicators, in turn, showed the perceived benefits accrued to individual farmers. In the present study, technologies were disseminated among direct respondents due to different perceived benefits, and according to their frequency, the best three derived benefits for Tech. 1 were in the order of better yield > less pest (means less cost involvement) > better profit. For Tech. 2, the order of benefits was like less water > better profit > children's education. However, for Tech. 3, the order was like less water > better-sized product (means better profit, less labour requirement, purchasing farm equipments) > less cost requirement = better plant growth. The benefits perceived by the farmers were highly technology specific. Achieving better yield was given prime

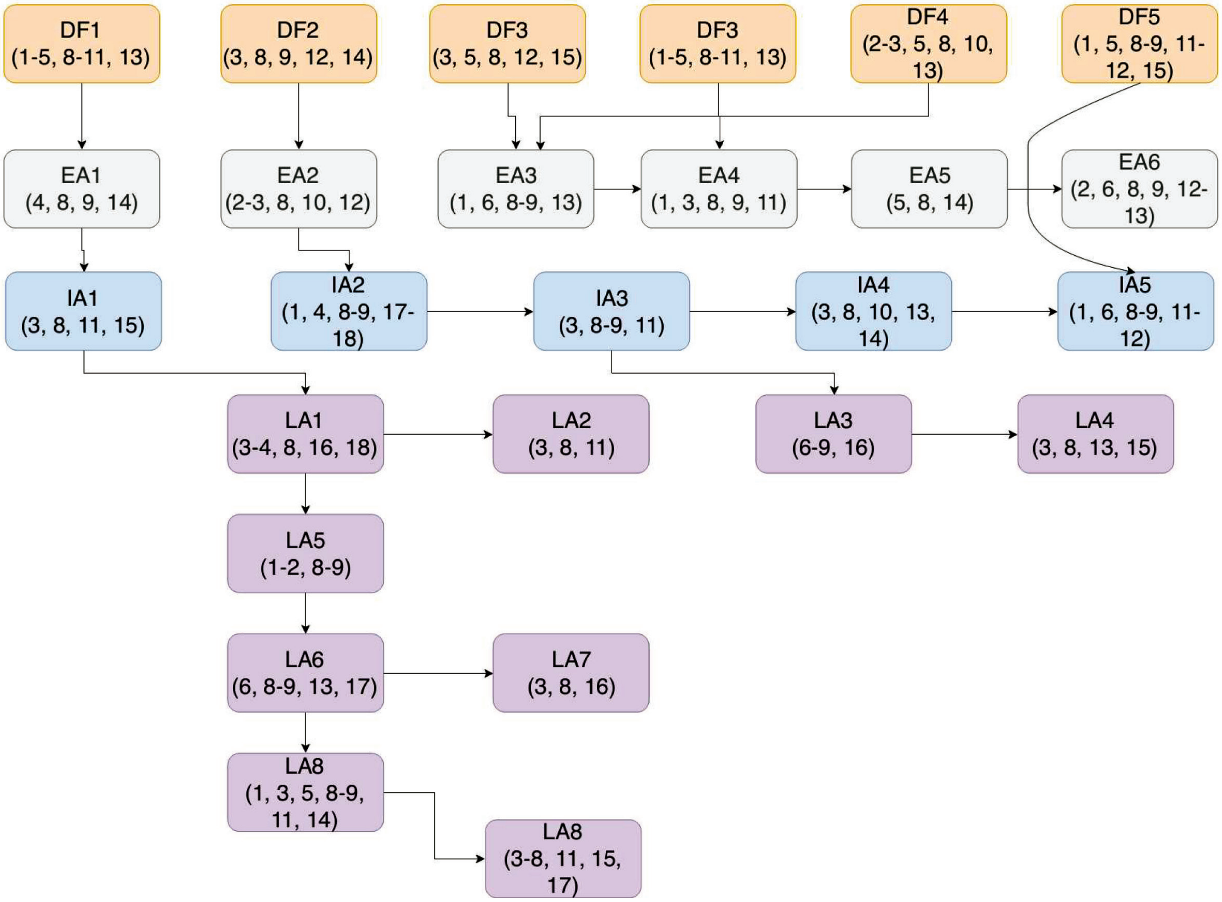

Fig. 2. *Participatory Innovation Tree for Tech.1. Boxes represent individual farmer. Within boxes, DF, EA, IA and LA represent demonstration farmers, early, intermediate and late adopter, respectively. Arrows link the source of technology to the adopter [numbers in the parentheses denote impact indicators affecting adoption of technology]*

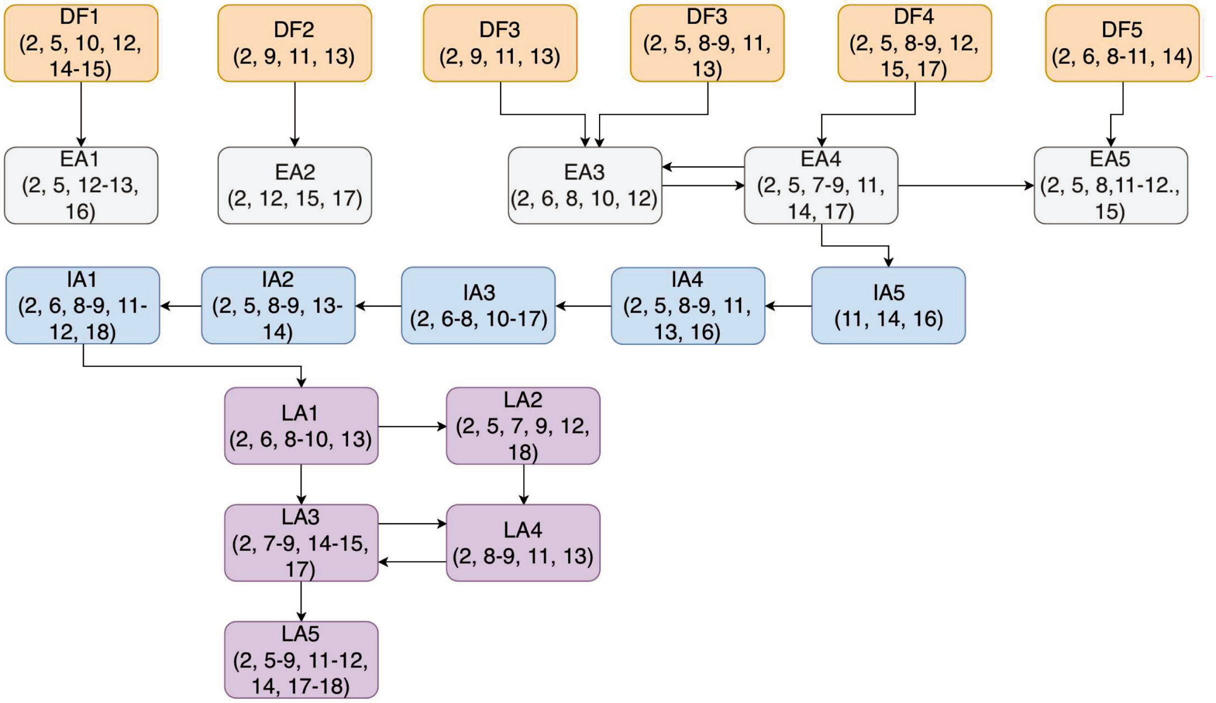

Fig. 3. *Participatory Innovation Tree for Tech.2. Boxes represent individual farmer. Within boxes, DF, EA, IA and LA represent demonstration farmers, early, intermediate and late adopter, respectively. Arrows link the source of technology to the adopter [numbers in the parentheses denote impact indicators affecting adoption of technology]*

Table 1. *Impact indicators as perceived by the farmers*

Impact indicators (II)	Perceived benefits
II-1	Less fertilizer
II-2	Less water
II-3	Less pest
II-4	Less fallow
II-5	Less cost
II-6	Better plant growth
II-7	Better size product
II-8	Better yield
II-9	Better profit
II-10	Less labour
II-11	Child education
II-12	Buying farm implements
II-13	Growing next crop
II-14	Buying medicine
II-15	Repairing home appliances
II-16	Pond cleaning
II-17	Pisciculture
II-18	Own consumption

importance while adopting Tech. 1. However, less water requirement was most important while adopting Tech. 2 and 3. Gaining better profit was the single common factor that had been given preference while adopting any of these three technologies.

Impact of adopted practices

We used spider diagrams for getting an idea of the impact of method demonstrations on farming community in terms of different impact indicators (identified through PIT). The Tech. 1 *i.e.* paira cropping of lathyrus in paddy field mostly resulted in better crop yield (than sole cropping) (II-8), lesser pest incidence (II-3) and better profit (II-9) (Fig. 5). Higher yield and profit of *paira*-cropped lathyrus had also been confirmed by Jana *et al*. (2000). Results also revealed lower pest population in such systems. Insects are normally attracted to and concentrated on their food plant resources which are more easily found or more apparent in mono-cropping systems. Finch and Collier (2000) observed that insects settle on plants only when various host plant factors such as visual stimuli, taste, and smell are satisfied. This is more likely in mono-cropping than in *paira* cropping.

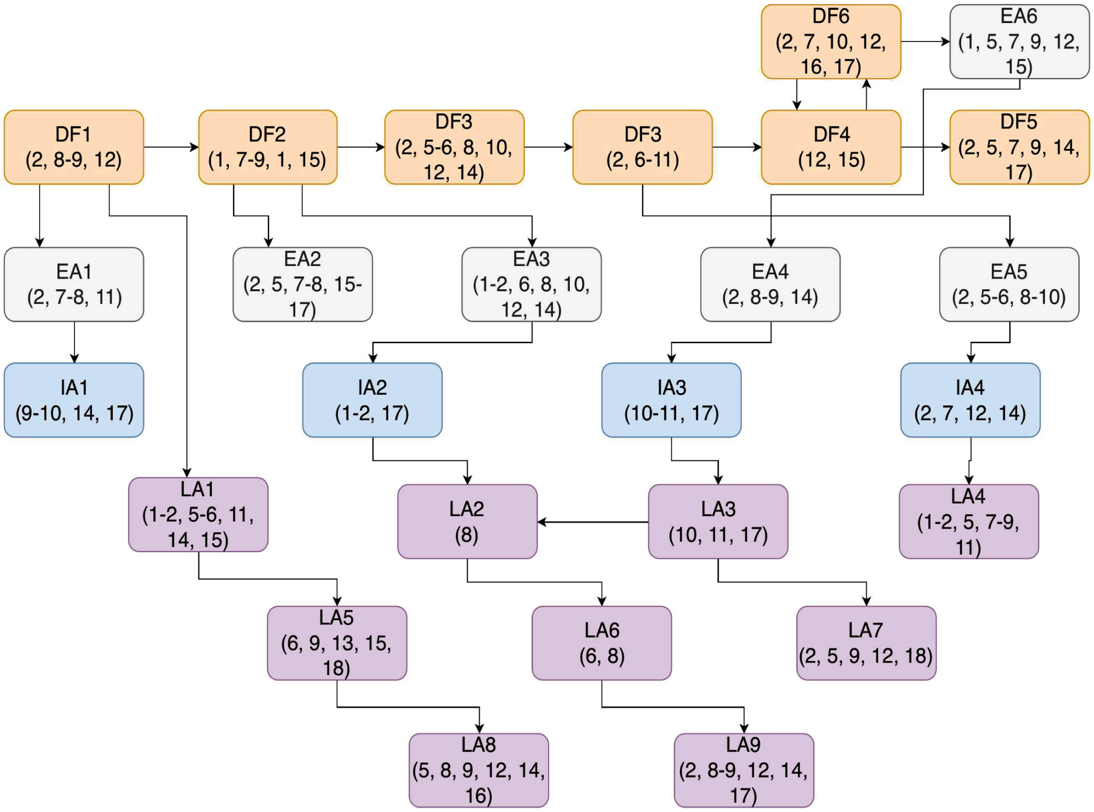

Fig. 4. *Participatory Innovation Tree for Tech.3. Boxes represent individual farmer. Within boxes, DF, EA, IA and LA represent demonstration farmers, early, intermediate and late adopter, respectively. Arrows link the source of technology to the adopter [numbers in the parentheses denote impact indicators affecting adoption of technology]*

There were observed impacts in terms of less water requirement (II-2), better yield (II-8) and profit (II-9) due to the adoption of both Tech. 2 *i.e.* use of water saving options (drip irrigation + straw mulching) in tomato and Tech. 3 *i.e.* use of conservation tillage and paddy straw mulching in potato (Fig. 5). In vegetables, lesser water requirement along with higher productivity and economics in case of drip irrigation as compared to conventional irrigation methods had previously been confirmed by other investigators (Hanson and May, 2003; Reddy *et al.*, 2015). Soil salinity under drip irrigation may affect crop yield less than other irrigation methods. Subsurface drip irrigation also provided better water management late in the growing season of tomato crop, while careful management was done to prevent excessive deficit irrigation and phytophthora due to overly wet soil (Hanson and May, 2003).

Sustainable intensification of adopted technologies

The changes in fertilizer application due to technology adoption are shown in Fig. 6. Except for P and K fertilizer, application in Tech. 2 and K fertilizer in Tech. 3, overall fertilizer application rate was reduced after the adoption of technologies as compared to farmers' previous practices. Regarding productivity indicator, the system productivity based on rice equivalent yield (REY) increased with all three demonstrated technologies (Fig. 7). Another productivity indicator *i.e.* sustainable yield index (SYI) was used to compare the sustainability amongst the three technologies (Fig. 8). It was observed that mean SYI was almost same for all three technologies and had a value of <1.0. However, the value of standard deviation (σ) was lowest for Tech. 1 and thus the same technology can be concluded as the most sustainable for the study location because of their least variability.

All the technologies assessed, in the present study, was better than farmers' practices of the previous year in terms of economic indicators namely net return (Fig. 9) and B:C ratio (Fig. 10). These findings indicated

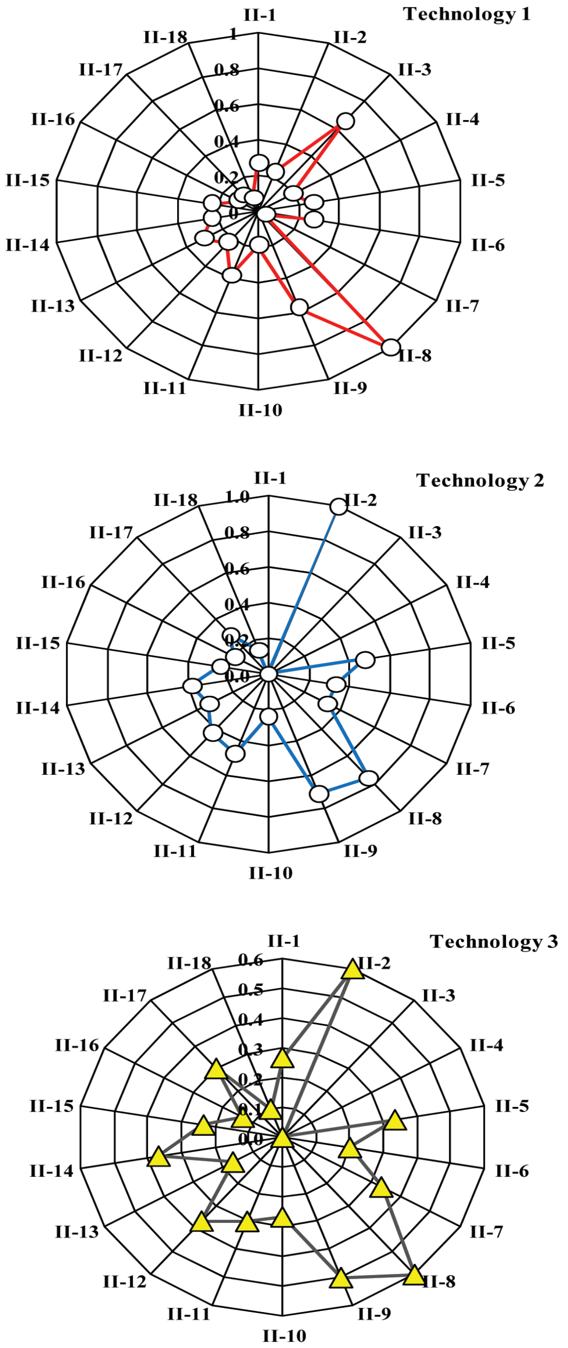

Fig. 5. *Spider diagram showing the mean impact of Tech. 1, 2 and 3 on the adopters in terms of different impact indicators*

improved sustainability of the technologies after their use in the farmers' field for several years.

The outcomes of the present study were location-specific and gave an estimation of the overall impact of technologies on the farmers. Still, further study on quantitative evaluation of technology-spread can be

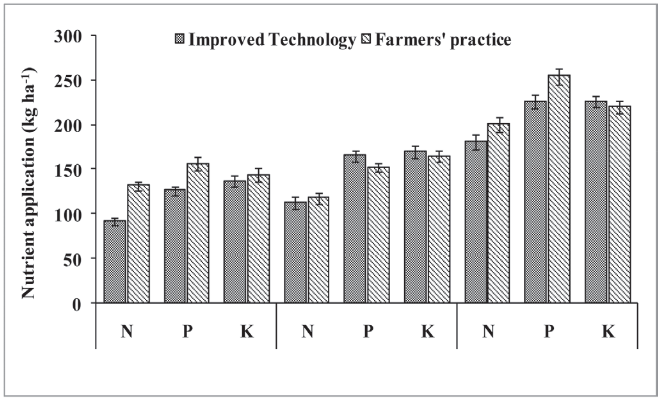

Fig. 6. *Changes in nutrient application after the adoption of Tech. 1, 2 and 3 farmers' practices against Tech. 1, 2 and 3 were sequential cropping (without overlapping) of lathyrus after rice, conventional method of irrigation in tomato and conventional sowing method for potato, respectively*

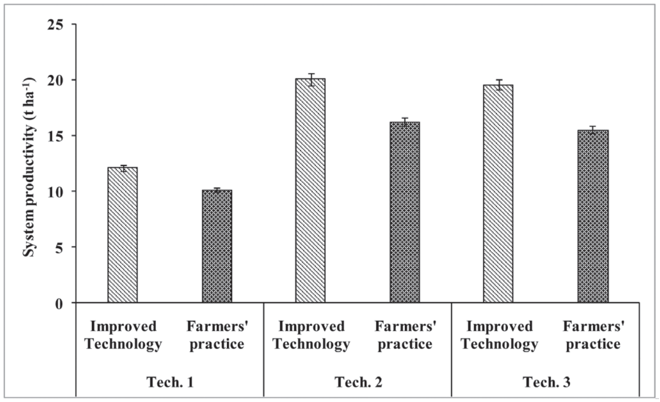

Fig. 7. *Changes in system productivity (based on rice equivalent yield) after adoption of Tech.1, 2 and 3; farmers' practices against Tech. 1, 2 and 3 were sequential cropping (without overlapping) of lathyrus after rice, conventional method of irrigation in tomato and conventional sowing method for potato, respectively.*

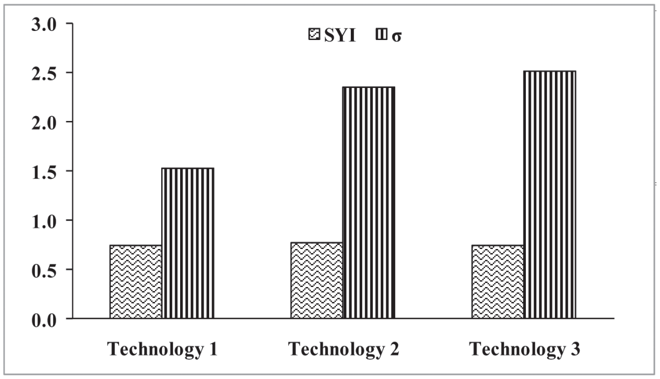

Fig. 8. *Productivity indicator i.e. sustainable yield index (SYI) and standard deviation of the system productivity (σ) after adoption of the technologies*

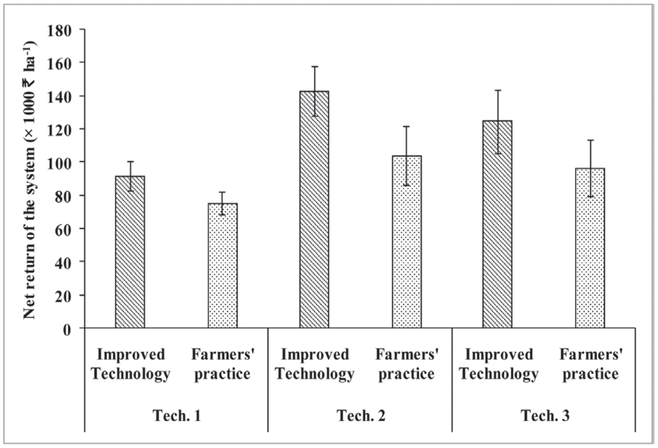

Fig. 9. *Changes in net return of the system after adoption of Tech.1, 2 and 3; farmers' practices against Tech. 1, 2 and 3 were sequential cropping (without overlapping) of lathyrus after rice, conventional method of irrigation in tomato and conventional sowing method for potato, respectively.*

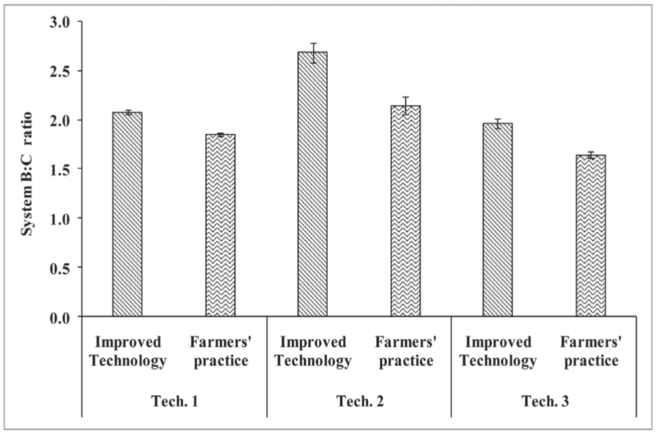

Fig.10. *Changes in system B:C ratio after adoption of Tech. 1, 2 and 3; farmers' practices against Tech. 1, 2 and 3 were sequential cropping (without overlapping) of lathyrus after rice, conventional method of irrigation in tomato and conventional sowing method for potato, respectively.*

undertaken. However, some very relevant information like the sustainability of technologies, perceived benefits of technologies, preference of the farmers, etc. can be prearranged by the researchers and policymakers before going for any intervention in the area.

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