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## Productivity and profitability assessment of organically grown vegetables embedded in rice based cropping sequences in Sikkim Himalayas, North East India

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### Abstract

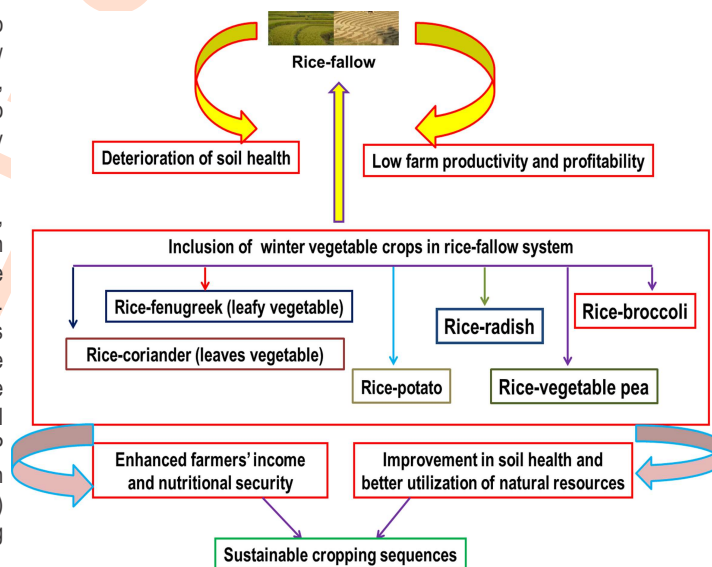
**Aim :** The objective of the present study was to identify economically viable, profitable and resource efficient vegetables embedded rice-based cropping sequences under organic management for marginal and small farmers of Sikkim Himalayas, India.

**Methodology :** Three-year fixed plot study was conducted to evaluate seven rice-based cropping sequences viz., rice-fallow (farmers' practice), rice-fenugreek (leafy vegetable), rice-coriander (leaves), rice-radish, rice-broccoli, rice-potato and rice-vegetable pea were replicated four-times in a completely randomized block design.

**Results :** Among the various rice – based cropping sequences, cultivation of rice-coriander (leaves) recorded higher production (67.3 kg ha<sup>-1</sup> day<sup>-1</sup>), system productivity (24.6 t ha<sup>-1</sup>), relative economic efficiency (1040%) and net returns (376.1x10<sup>3</sup>). However, rice-broccoli and rice-vegetable pea sequences recorded 8.6 and 4.4% higher B: C ratio, respectively, over the rice-coriander system. With regards to soil health, rice – vegetable pea cropping sequences resulted in maximum improvement in soil organic carbon (SOC) (1.26%), available soil N (415.2 kg ha<sup>-1</sup>), P (22.8 kg ha<sup>-1</sup>) and K (411.5 kg ha<sup>-1</sup>), soil microbial biomass carbon (SMBC) (344.7 µg MBC g<sup>-1</sup> soil), dehydrogenase activity (DHA) (24.0 µg TPFg<sup>-1</sup> soil h<sup>-1</sup>) and fluorescin di acetate (FDA) (38.8 µg FDAg<sup>-1</sup> soil h<sup>-1</sup>) among the cropping sequences.

**Interpretation :** Induction of vegetables in rice-fallow system under assured irrigation condition of Sikkim Himalayas, India not only enhances the farm productivity and profitability but also sustain the soil health on long term basis. Thus, rice-vegetable pea/coriander/broccoli based production systems under organic management hold great promises for sustaining livelihood of organic growers in Sikkim Himalayas over conventional rice-fallow system.

**Key words:** Cropping sequence, North-eastern Himalayas, Organic farming, Rice-fallow, Soil health



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## Introduction

Rice (*Oryza sativa* L.), the staple food crop of North Eastern Himalayan region (NEHR) of India is cultivated in ~3.5 million ha that accounts for almost 8% area and 6.5% of India's total rice production (Yadav *et al.*, 2019a). Therefore, rice-based cropping is a predominant production practice across the landforms of North Eastern Indian Himalayas (NEIH) (Yadav *et al.*, 2017a). Furthermore, the region has ~1.5 Mha rice–fallow land that offers large potential for horizontal expansion of high value crops (Yadav *et al.*, 2019a). Almost 30% area of 1.5 Mha rice–fallow has assured irrigation. Rice mono-cropping in NEIH is risk prone economic activity which cannot sustain the farm productivity and food security in the region (Babu *et al.*, 2016). Thus, the future of agriculture in NEIH region depends on efficient use of natural resources, crop diversification and adoption of ecological principles promoting agroecosystem resilience and steadiness (Choudhary *et al.*, 2013; Paul *et al.*, 2014). Sustaining crop productivity under decreasing land and water resources is becoming major challenge in North Eastern Indian Himalayas (Babu *et al.*, 2014).

The North Eastern Indian Himalayas region has huge potential for organic farming due to congenial environmental conditions to grow diverse crops, suboptimal/negligible use of fertilizers (<12 kg ha<sup>-1</sup>) and synthetic agrochemicals, and abundance of organic manure, especially plant biomass (Patel *et al.*, 2014). Thus, resource efficient cropping systems need to be identified for successful organic farming in the region to enhance farm productivity and income, besides sustaining soil health (Choudhary *et al.*, 2013). Sikkim was declared as the first “100% organic” state of India on January 18, 2016 by the Honorable Prime Minister of India. Organic farming is mainly practiced through an ecological perspective (Scialabba and Muller-Lindenlauf, 2010). The crop productivity under organic farming is typically lower than conventional production systems (Seufert *et al.*, 2012), however, the magnitude of yield reduction is highly specific and depends on the type of crops grown, soil and climatic conditions. Hence, the state is largely deficient of cereals, especially rice (74%) and vegetables to feed its population. Continuous mono-cropping of rice for longer periods on the same piece of land causes soil fatigue resulting in poor crop productivity which has widened the demand and supply gap in the region. Self-sufficiency and nutritional security in the state are not possible without embedding vegetables in rice–fallow areas, even though vegetable production requires much higher inputs as compared to field crops (Congreves and Van Eerd, 2015).

Furthermore, some vegetable crops return very less amount of organic matter to the soil after harvest (Brennan and Acosta-Martinez, 2017). Hence, vegetable cultivation may have negative effects on soil health. Unfortunately, agricultural researchers have basically overlooked soil health status in vegetable–based cropping sequences, and this embodies a noticeable research gap which must be addressed in order to feed the burgeoning population in sustainable manner. Being a

staple food, rice cannot be replaced with other crops during rainy season. Thus, the only appropriate option is to identify suitable high value crops for the winter season under irrigated ecosystems of the state. Realizing this, significant thrust has been made on the inclusion of high value and high volume vegetable crops in rice–fallow systems to improve the economic condition of marginal and small farmers (Pooniya *et al.*, 2015). Intensification of rice–fallow system is an effectual approach for achieving food and nutrition security, poverty alleviation, employment generation, prudent use of land and water resources, sustainable agricultural development and overall environmental quality improvement (Hegde *et al.*, 2003). In the era of resource attenuation, resource use efficiency is an important aspect for considering the suitability of a cropping system (Babu *et al.*, 2014), hence, the selection of crops and cropping systems needs to be suitably planned to harvest the synergism among the various crops in a production system towards efficient utilization of resource base and to increase overall farm productivity (Anderson, 2005).

The major challenge is to produce more food per unit land with fewer resources in order to feed the galloping/burgeoning population on one hand and to sustain natural resources on the other. In view of this, it would be expedient, if more profitable and economically viable sequences can be introduced in the organically managed marginal and small farm land in the mid hills of Sikkim Himalayas under the prevailing rice–fallow sequence for achieving long-term productivity and profitability in a sustainable manner. Therefore, an attempt was made to assess viable, profitable and resource efficient cropping system as an alternative to rice–fallow systems in Sikkim Himalayan region of India.

## Materials and Methods

**Experimental site and climate:** A fixed plot field experiment was conducted for three consecutive years (2013-14, 2014-15 and 2015-16) at experimental farm of ICAR-National Organic Farming Research Institute (formerly, ICAR Research Complex for NEH Region Sikkim Centre), Tadong, Sikkim, India. The experimental site received total rainfall of 1837, 2127 and 2598 mm/annum during 2013-14, 2014-15 and 2015-16, respectively. Variation in maximum temperature was observed during three years; during 2013-14 the maximum temperature was recorded in September (28.2°C). However, the maximum temperature during 2014-15 and 2015-16 was recorded in July (28.2°C; 27.57°C). The minimum temperature remained constant and the lowest temperature during three years was recorded in January. The soil of experimental site was clay loam in texture with initial pH, soil organic carbon, available N, P and K as 5.7, 11.7 g kg<sup>-1</sup>, 347.1 kg ha<sup>-1</sup>, 14.8 kg ha<sup>-1</sup> and 371.7 kg ha<sup>-1</sup>, respectively.

**Treatment and crop culture:** Seven cropping sequences *viz.*, rice–fallow (farmers' practice), rice–fenugreek (leafy vegetable), rice–coriander (leaves), rice–radish, rice–broccoli, rice–potato and rice–vegetable pea were replicated four times in a completely randomized block design. With a view to avoid mixing of

manure/compost among the plots, individual plots were thoroughly prepared manually with the help of a spade in each season. The amount and type of organic manure/compost applied in each crop is given in Table 1.

The average nutrient content in farmyard manure (FYM) and vermicompost (VC) was as follows: N: 0.55 and 2.03%,  $P_2O_5$ : 0.22 and 0.88% and  $K_2O$ : 0.54 and 1.25%, respectively. During all the years, crops were grown with the recommended organic cultivation practices (Avasthe *et al.*, 2016). Properly decomposed organic manure/compost was applied and incorporated in the soil at the time of last tilling before sowing/planting of each crop. Organic solution (mixture of water, cow slurry/urine and vermiwash in 10:1:1 ratio) was sprayed after each cut of fenugreek and coriander during three years. The details of important agronomic activities and inputs used in different crop in various cropping sequences are given in Table 1. The nursery of rice crop was raised in the first fortnight of June and transplanted in first week of July in the main field. Irrespective of treatments, rice was harvested in the first fortnight of November. The winter season crops were sown/planted in the second fortnight of November and harvested at different times.

#### Calculation of different productivity and economic indices:

Rice grain equivalent yield and economics were calculated considering the prevailing market prices, rice grain (₹2000  $t^{-1}$ ), potato (₹2000  $t^{-1}$ ), vegetable pea (₹4000  $t^{-1}$ ), coriander (₹6000  $t^{-1}$ ), fenugreek (₹4000  $t^{-1}$ ), radish (₹2000  $t^{-1}$ ) and broccoli (₹4000  $t^{-1}$ ). Gross and net returns were calculated by using prevailing market price of different commodities during the year 2015-16. The productivity of different crops in sequences was computed by converting the yield of all crops into rice grain equivalent yield (RGEY). Production Efficiency is the capacity of a particular production system to produce economic yield per unit time. Production efficiency values in terms of  $kg\ ha^{-1}\ day^{-1}$  were worked out by multiplying total production with mean of rice equivalent yield in a crop sequence divided by 365 days. The values of production efficiency and monetary advantage in terms of ₹ $ha^{-1}\ day^{-1}$  were calculated by net monetary returns of the sequence divided by 365 days. Relative Production Efficiency (RPE) and relative economic efficiency (REE) as production capacity and economic gains over of the system in relation to the existing systems were calculated by the formula suggested by Yadav *et al.* (2017b).

**Soil sampling and analysis:** Soil samples were obtained (500 g composite sample, one sample from each plot) from 0–20 cm depth for analyzing the soil organic carbon (SOC), available nitrogen, phosphorus and potassium, soil microbial biomass carbon (SMBC), dehydrogenase activity (DHA) and fluorescein diacetate (FDA) activity before initiation and after completion of 3 years of experiment. The pH of soil was determined with a digital pH meter having glass electrode, in 1: 2.5 soil-water suspensions (Jackson, 1973). The SOC, available N, P and K were determined by the procedure suggested by Prasad *et al.* (2006). Fresh soil samples stored at freezing temperature was used for analyzing

SMBC, DHA and FDA. SMBC was estimated by soil fumigation technique (Anderson and Ingram, 1993). DHA was estimated by the procedure described by Tabatabai (1982) by reducing 2, 3, 5-triphenyl tetrazolium chloride (Casida *et al.*, 1964). Fluorescein diacetate (FDA) activity was estimated as per the method outlined by Green *et al.* (2006).

**Statistical analyses:** All the data obtained from different cropping sequences for consecutive three years was averaged and subjected to analysis of variance (Gomez and Gomez, 1984). The least significant difference was computed to determine the treatments that were statistically different.

## Results and Discussion

The perusal of data in Table 2 shows that inclusion of leguminous vegetables enhanced the average rice productivity. Induction of fenugreek during winter season registered maximum gain in rice productivity (5.38%) over rice–fallow system among the winter crops, followed by vegetable pea. In general, all the vegetable embedded cropping sequences were found more productive over the farmers' practice, *i.e.*, rice–fallow of the region (Table 2). Cultivation of multiple crops having different nutrients input demand lead to improved soil fertility (Lin, 2011), nutrients rich soils optimize water use by plants and improve overall crop productivity (Makate *et al.*, 2016). While comparing the total productivity of intensified cropping sequences in terms of rice grain equivalent yield (RGEY) significantly higher RGEY was recorded with rice-coriander (leaves) sequence (24.57  $t\ ha^{-1}$ ) (Table 2), followed by rice-potato cropping sequence (22.73  $t\ ha^{-1}$ ) whereas the lowest RGEY (3.90  $t\ ha^{-1}$ ) was recorded when the field was left fallow after harvesting of rice. Plant architecture, leaf structure and morphological features determine the photosynthetic efficiency, and hence the overall performance of crop plants (Mathan *et al.*, 2016). Optimization of these developmental traits thus increased the biomass and crop yield. Coriander has great potential in biomass production which resulted in high system productivity of the cropping sequences.

The higher rice grain equivalent yield (RGEY) of rice–coriander (leaves) system was also due to higher sale price of coriander crops in the market. Correspondingly, the maximum system production efficiency (67.31  $kg\ ha^{-1}\ day^{-1}$ ) was recorded with rice – coriander (leaves) sequence followed by rice–potato (Table 2). Crop yield and sale price of the produce greatly influences the overall return and production efficiency of various sequences (Babu *et al.*, 2016) and results in higher production efficiency. However, the lowest production efficiency was recorded in rice–fallow system. Similar results were also reported by Sharma *et al.* (2004); Singh *et al.* (2007) and Prajapat *et al.* (2018) with intensified systems over the existing production systems. Similarly, relative production efficiency (RPE), *i.e.*, the capacity of newly designed sequence for production in relation to existing system was maximum with rice-coriander sequence (530%), followed by rice-potato sequence (483%). Saha and Ghosh (2010) and Babu *et al.* (2016) have also reported higher

**Table 1:** Agronomic activities and inputs used in different cropping sequences during three consecutive years (2013-14, 2014–15 and 2015-16) at Tadong, Sikkim

Cropping sequence	Varieties/Genotypes		Average seed rate (kg ha <sup>-1</sup> )		Spacing (cm)		Organic manure (t ha <sup>-1</sup> year <sup>-1</sup> )			
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif		Rabi	
							FYM	VC	FYM	VC
Rice–fallow	Shahsarang	-	35	-	20 × 10	-	6.0	1.5	--	--
Rice–fenugreek (leafy vegetable)	Shahsarang	Rajendra Kranti	35	35	20 × 10	30 × 10	6.0	1.5	3.0	0.75
Rice–coriander (leaves)	Shahsarang	Super Midori	35	25	20 × 10	30 × 10	6.0	1.5	8.0	2.0
Rice–radish	Shahsarang	Pusa Chetki	35	12	20 × 10	30 × 10	6.0	1.5	8.0	2.0
Rice–broccoli	Shahsarang	F-1 hybrid	35	0.45	20 × 10	45 × 45	6.0	1.5	8.0	2.0
Rice–potato	Shahsarang	Holland local	35	2500	20 × 10	45 × 15	6.0	1.5	10.0	4.0
Rice–vegetable pea	Shahsarang	VRP 6	35	75	20 × 10	30 × 10	6.0	1.5	3.0	0.75

FYM: Farm yard manure; VC: Vermicompost

**Table 2 :** Average productivity of different crops in rice-based cropping sequences during three consecutive years (2013-14, 2014–15 and 2015-16) at Tadong, Sikkim (average of 3 years)

Cropping sequence	Productivity of first crop (t ha <sup>-1</sup> )	Productivity of second crop (t ha <sup>-1</sup> )	System productivity (t ha <sup>-1</sup> )	Production efficiency (kg ha <sup>-1</sup> day <sup>-1</sup> )	Relative production efficiency (%)
Rice–fallow	3.90	--	3.90	10.68	0.00
Rice–fenugreek (leafy vegetable)	4.11	7.24	18.60	50.96	377
Rice–coriander (leaves)	3.93	6.87	24.57	67.31	530
Rice–radish	3.90	11.2	15.15	41.51	289
Rice–broccoli	4.00	8.56	21.12	57.86	442
Rice–potato	3.98	18.7	22.73	62.27	483
Rice–vegetable pea	4.07	7.65	19.31	52.90	395
Sem±	0.06	--	0.62	1.69	--
LSD (P=0.05)	0.16	--	1.55	4.25	--

RPE with intensified systems over existing cropping system under diverse nutrient management scenarios. With regards to financial analysis the highest gross return (₹491.13 × 10<sup>3</sup>) and net return (₹376.13 × 10<sup>3</sup>) was observed with rice–coriander (leaves) sequence (Table 3). This was mainly due to higher market price of the second crop. The maximum B:C ratio was observed under rice–broccoli (4.30) system, which remained statistically on par with rice–vegetable pea (4.11) and rice–coriander (leaves) (3.96) cropping sequences but significantly higher than rest of the sequences. While assessing the sustainability of cropping sequences, profitability is a key indicator. Rice–coriander (leaves) cropping sequence registered the maximum profitability (₹1031 ha<sup>-1</sup> day<sup>-1</sup>), followed by rice–broccoli system (₹889 ha<sup>-1</sup> day<sup>-1</sup>). On the other hand, the lowest net return (₹33 × 10<sup>3</sup>) and B: C ratio (1.71) was recorded with the rice–fallow cropping sequence. This may be attributed to variation in yield, cost of cultivation and prices of economic produce of succeeding crops in sequences. Similar results were also reported by Prasad *et al.* (2013) and

Manjunath *et al.* (2018). In the case of relative economic efficiency (REE), all the intensified sequences had higher economic gain over the rice–fallow sequence. Among the intensified sequences, rice–coriander (leaves) sequence recorded the highest economic gain (1040%) over the rice–fallow sequence (Table 3). In contrary, the rice–radish sequence resulted in the lowest economic gain (533%) over the rice–fallow sequence. Inclusion of more number of crops in exiting cropping sequences resulted in higher productivity, employment generation, which ultimately turned in higher economic output over routine cropping sequences (Mukherjee, 2010; Prasad *et al.*, 2014).

Declining soil health is the fundamental cause of decreasing crop productivity and environmental squalor. Maintenance and improvement of soil quality through cropping sequences is important to sustain agricultural productivity. In the present investigation, the soil health was assessed in terms of

**Table 3:** Economic efficiency of rice-based cropping sequences embedded with vegetable crops during three consecutive years (2013-14, 2014-15 and 2015-16) at Tadong, Sikkim (average of 3 years)

Cropping sequence	Gross returns (₹x10 <sup>3</sup> )	Net returns (₹x10 <sup>3</sup> )	B:C ratio	Profitability (₹ha <sup>-1</sup> day <sup>-1</sup> )	Relative economic efficiency (%)
Rice-fallow	78.00	33.00	1.71	90	0.00
Rice-fenugreek (leafy vegetable)	371.99	270.99	3.69	742	721
Rice-coriander (leaves)	491.13	376.13	3.96	1031	1040
Rice-radish	303.00	209.00	3.21	573	533
Rice-broccoli	422.14	324.14	4.30	889	882
Rice-potato	454.87	298.87	2.90	818	806
Rice-vegetable pea	386.06	292.84	4.11	801	787
SEm±	4.26	3.44	0.14	10.11	-
LSD (P=0.05)	10.74	8.68	0.36	25.48	-

**Table 4:** Soil pH, SOC, and available NPK after 3 years of rice-based cropping sequences embedded with vegetable crops at Tadong, Sikkim

Cropping system	pH	SOC (%)	Available N (kg ha <sup>-1</sup> )	Available P (kg ha <sup>-1</sup> )	Available K (kg ha <sup>-1</sup> )
Rice-fallow	5.7	1.19	362.0	15.34	384.3
Rice-fenugreek (leafy vegetable)	5.9	1.25	406.0	19.99	410.4
Rice-coriander (leaves)	5.8	1.22	377.3	16.39	392.7
Rice-radish	5.8	1.19	383.0	16.68	392.0
Rice-broccoli	5.9	1.20	396.4	17.31	395.0
Rice-potato	5.8	1.18	384.6	18.07	391.3
Rice-vegetable pea	5.9	1.26	415.2	22.76	411.5
SEm±	0.022	0.039	5.84	0.79	4.47
LSD (P=0.05)	NS	NS	14.73	1.98	11.26

**Table 5:** Changes in soil biological parameters after 3 years of rice-based cropping sequences embedded with vegetable crops at Tadong, Sikkim

Cropping system	Soil microbial biomass carbon (µg MBC g <sup>-1</sup> soil)	Dehydrogenase activity (µg TPFg <sup>-1</sup> soil h <sup>-1</sup> )	Fluorescin di acetate (µg FDA g <sup>-1</sup> soil h <sup>-1</sup> )
Rice-fallow	326.2	14.73	35.00
Rice-fenugreek (leafy vegetable)	337.9	19.80	38.33
Rice-coriander (leaves)	327.7	18.90	37.33
Rice-radish	331.8	17.33	34.67
Rice-broccoli	337.7	19.00	36.00
Rice-potato	332.1	18.20	31.67
Rice-vegetable pea	344.7	24.00	38.80
SEm±	3.05	0.82	1.28
LSD (P=0.05)	7.68	2.07	3.22

change in soil pH, SOC, available NPK, soil microbial biomass carbon (SMBC), dehydrogenase (DHA) and fluorescin di acetate (FDA) activities after three-year fixed plot study. The cropping sequences had failed to statistically affect the soil pH and SOC. However, among the cropping sequences, the maximum gain in SOC status was observed with rice-vegetable pea sequence followed by rice-fenugreek sequence. Soil available N, P and K were significantly affected by cropping sequences. Significantly

higher values of N (415.2 kg ha<sup>-1</sup>), P (22.8 kg ha<sup>-1</sup>) and K (412 kg ha<sup>-1</sup>) were reported from the rice-vegetable pea sequence followed by the rice-fenugreek (leafy vegetables) sequence. This was due to the fact that vegetable pea has unique property of capturing/storing the atmospheric nitrogen in the soil, besides leaving higher amount of root biomass. Legume acts as a reagent to increase availability of native and fixed P (Ghosh *et al.*, 2007). Phosphorus supply in legumes enhances excretion of amino

acids, increases the fixation of atmospheric nitrogen and improves the soil fertility (Nimje and Seth, 1988). These results corroborated the findings of Yadav *et al.* (2013 a). Inclusion of leguminous vegetables like pea and fenugreek increases available soil nitrogen by 14.64% and 12.15% over rice–fallow sequence, respectively, in three years. The least improvement in soil nitrogen (N) and potassium (K), over rice–fallow system was noticed with rice–coriander sequence. In respect of available potassium (K), least improvement in soil K over rice–fallow sequence was recorded in the rice–potato sequence. This might be due to K devouring characteristic of potato crop. The negative impact of continuous cropping of the same species year after year on the same piece of land on soil organic matter, crop yields, soil biological parameters and fertility are well documented (Gaudin *et al.*, 2015; Tiemann *et al.*, 2015). Consequently, crop diversification has been recommended as the best management practice to improve farm productivity and to arrest deterioration of soil quality (Tilman *et al.*, 2002; Yadav *et al.*, 2019b). In general, all the soil biological parameters (SMBC, DHA and FDA) under study had improved due to the inclusion of vegetables in the rice–fallow sequence (Table 5).

However, among the intensified cropping sequences rice – vegetable pea recorded the highest value of SMBC (344.7  $\mu\text{g MBC g}^{-1}$  soil), dehydrogenase (24.00  $\mu\text{g TPF g}^{-1}$  soil  $\text{h}^{-1}$ ) and FDA (38.80  $\mu\text{g FDA g}^{-1}$  soil  $\text{h}^{-1}$ ) followed by rice–fenugreek (leafy vegetable) sequence. This might be due to the inherent nature of these crops and also due to comparatively higher plant population than others which might have contributed more organic matter to the soil. Soil microorganisms play an important role in soil nutrient cycling and soil productivity. Similarly, soil enzymatic activity assay is the best indicator to measure the quality status of soils. Enzymes are vital soil components involved in soil nutrient dynamics. Enzymatic activity in the soil milieu is considered to be the chief contributor of overall soil microbial activity (Frankenberger and Dick, 1983), resistance and resilience capacity of soil (Kumar *et al.*, 2014) and is involved in organic matter turnover. Improvement in soil biological parameters due to inclusion of leguminous vegetables in rice–based system under organic management scenario has also been reported by Yadav *et al.* (2013b). Thus, the study concluded that induction of vegetables in rice–fallow system under assured irrigation in Sikkim Himalayas not only enhances the farm productivity and profitability but also sustains soil health. Therefore, it is recommended that growers can wisely select any of the rice–vegetable pea/coriander (leaves)/broccoli cropping sequences under organic management as alternatives to rice–fallow sequence/system for sustaining their livelihood security, especially in the mid hills of Sikkim Himalayas.

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