



Crop diversification for enhancing productivity and profitability under modified land configuration of Eastern Himalayas

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ABSTRACT

The mono-cropped rice system in the valley lands of the Eastern Himalayas has low productivity. To address this, a two-year field experiment (2022–2023) was conducted using a modified raised and sunken bed (RSB) system under organic nutrient management. The factorial randomized block design (FRBD) included three replications. In sunken beds, three rice varieties (Megha Aromatic, Shahsarang-1, and IR-64) were grown, followed by no-till pea, while in raised beds, three vegetable-based systems (okra-potato, okra-French bean, and okra-carrot) were tested under three organic nutrient sources: 100% farmyard manure (FYM), vermicompost (VC), and 50% FYM + 50% VC. Results indicated that Shahsarang-1 rice (4.73 Mg/ha) and the combined FYM + VC treatment (4.49 Mg/ha) produced the highest grain yield. Peapod yield (5.23 Mg/ha) and vegetable yields were also highest under integrated FYM and VC use. The rice (Shahsarang-1)-pea system (sunken beds) and okra-carrot system (raised beds) achieved maximum system productivity, production efficiency, and sustainability index. These systems also recorded the highest economic returns (gross: 2812 and 5833 USD/ha/year; net: 1957 and 3825 USD/ha/year). Organic manure application improved soil organic carbon and nutrient availability, enhancing soil health. Adopting the RSB system with organic practices can significantly improve productivity, profitability, and soil health, ensuring better livelihoods for farmers and environmental sustainability in the Eastern Himalayas.

Key words: Organic farming, Raised and sunken beds, Soil health, Vegetables-based system

The North Eastern (NE) India, comprising the Indian states of Sikkim, Arunachal Pradesh, Nagaland, Manipur, Meghalaya, and Mizoram, receives almost 2450 mm of rainfall per annum and uses negligible amounts of agrochemicals with a decent amount of the soil organic carbon (SOC) content. Nevertheless, the twin challenges of heavy rainfall in monsoon and acute water shortage in winter make crop production quite challenging in the region. Thus, rainfed lowland rice is a major production system covering ~0.998 million hectares (Mha) with an average annual productivity of ~1.8 t ha⁻¹ (Baishya *et al.*, 2009). Rice is mostly cultivated in valley land under rainfed conditions and the majority of areas remain fallow after rice harvesting (Das *et al.*, 2015). In the North Eastern Hill

Region of India due to very high rainfall in the rainy season (>2000 mm), drainage is problematic in valley land during the rainy season (Das *et al.*, 2015). Even in the winter season, the water table in the valley's foothills remains high mainly because of continuous seepage from surrounding hillocks and uplands (Layek *et al.*, 2022). The excess water from such lands comes down as runoff and creates m. Therefore, only rice is grown in the *kharif* season and after the rice harvest, it practically becomes impossible to grow a second crop. Raised and sunken bed land configuration (cutting and removing the surface soil layer from an area and filling/depositing on the adjacent area to a height of about 30-50 cm) allows year-round cultivation of vegetables/pulses and enhances cropping intensity and system productivity. This proper land configuration, such as permanent raised and sunken beds (RSB), combined with efficient organic nutrient management, allows crop diversification and enhances crop vis-à-vis soil productivity (Das *et al.*, 2015). As raised beds can be utilized for the cultivation of diverse vegetables such as okra, potato, carrot, and French bean as vegetables constitute an imperative portion of the diet of the Eastern

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Himalayan population, and in sunken beds, the *kharif* rice followed by vegetable peas under zero-till can be adapted to utilize residual soil moisture and replenish soil fertility (Das *et al.*, 2017). Due to cutting filling and recycling of on-farm residues, the soil health improves in this method of cultivation (Das *et al.*, 2015). Each of the systems works as a micro watershed, where the water from the raised area drains into the sunken area and facilitates in-situ rainwater harvesting structure. According to Das *et al.* (2015), the cropping intensity (CI) through RSB configuration can be increased up to ~300% in raised beds and ~200% in sunken beds. Further, the RSB considerably improves rice equivalent yield from 8.9 to 43.5 t ha⁻¹, the B:C ratio by 75.5–513.2%, and employment generation by 10 times compared to the farmer's practices (Gogoi *et al.*, 2022). Raised bed height was maintained as per the requirement of the crops, and water table and varies from 40 to 60 cm. In areas, where the water table was high and standing water was there at rice harvest, the proportion of raised bed area was reduced to 40 % and height was increased to provide a better moisture gradient. Selections of component crops need to be suitably planned for efficient utilization of the resource base and to increase overall system productivity (Das *et al.*, 2015; Layek *et al.*, 2022).

In the eastern Himalayas, the use of synthetic fertilizer is negligible and cultivation is mainly done on inherent soil fertility or little addition of organic manure causing below-optimum productivity (Das *et al.*, 2015). However, with the increase in population pressure, there is a need for technological backstopping for sustainable organic food production in the region (Layek *et al.*, 2023). The region is highly suitable for organic farming due to high soil organic carbon content rich biodiversity in flora and fauna, moderate agro-climatic conditions, plenty of rainfall, etc. (Patel *et al.*, 2015). Hence, the adoption of an organic package of practices will enhance the soil fertility and yield in these areas (Layek *et al.*, 2023). Additionally, the long-term usage of organic manures, viz., FYM and vermicompost, and the inclusion of legumes, viz., vegetable pea, lentil, and French bean, improve the soil health through biological nitrogen (N) fixation, improving microbial population, and restoring soil carbon (C) pools, thereby improving the resilience of agro-ecosystems (Layek *et al.*, 2014). Further, the diversification of crops also reduces the incidence of weeds, pests, and diseases and overall lessens the risk of crop failure, due to which proper implementation of well-planned crop rotations is fundamental to the success of organic systems (Patel *et al.*, 2015). Despite the region's high potential for vegetable production, there is still limited knowledge about suitable cropping sequences that can sustainably improve productivity, enhance farmers' income, and boost soil health.

Thus, there is a need for further research to evaluate vegetable-based cropping systems within modified land configurations to better understand their long-term effects on productivity, income, and soil fertility. To address these knowledge gaps, a field study was conducted to assess the impact of various vegetable-based cropping sequences on raised beds and rice-pulse systems in sunken beds to explore crop diversification strategies for enhancing agricultural productivity and building climate resilience in the North-Eastern Himalayas.

MATERIALS AND METHODS

A field experiment was conducted in 2022 and 2023 in a lowland organic farm of the ICAR RC for the NEH Region, Meghalaya, India. The experimental area lies in valley land at a coordinate of 25°30'N and 9°51'E and 950 m above mean sea level (MSL). Since, the initiation of the experiment in 2005, neither chemical fertilizer nor pesticides were used in the experimental plots. The area receives an average annual rainfall of 2450 mm in which >85% of rain is received in the months of April to October. While a negligible amount of rainfall is received during the winter months causing water stress. The average monthly minimum and maximum temperatures ranged from 12.0 to 20.5 °C and 23.3 to 29.3°C, respectively. The soil of the study area was sandy loam in texture with a low in soil *pH* (4.95), high soil organic carbon (18.5 g/kg), low available nitrogen (N) (240.1 kg/ha), and phosphorus (P) (9.30 kg/ha), and medium in available potassium K (251.6 kg/ha). The field was set up in a raised and sunken (RSB) layout with dimensions of 8.0 m length, and 1.25 m breadth by removing and placing soil on the adjacent area to make raised beds at a height of 30 cm for raising rainy and winter season crops. The experiment was laid out in a factorial randomized block design (FRBD) with three (03) replications. Further, the three rice varieties viz. Megha aromatic, Shawsarang-1, and IR-64 followed by pea was imposed on sunken beds, while, the three cropping systems viz. okra-potato, okra-French bean, and okra-carrot along with three (03) nutrient management i.e., 100% recommended dose farm yard manure (FYM), vermicompost (VC), and 50% FYM and VC. The rice was manually transplanted in the 1st fortnight of July at a spacing of 25 × 15 cm using ~ 25 days old seedlings. While the okra variety "Pusa Sawani" was dibbled in mid-June at a distance of 45 × 60 cm using as seed @ 15 to 20 kg/ha. Similarly, the winter season crops i.e. zero-till pea in sunken beds, and vegetables in raised beds such as carrots, French bean, and potato were planted in the first fortnight of January at a recommended distance, and seed rate. The description of crop management practices followed is presented in Table 1. The rice and okra were grown as a

rainfed crop, while during the winter season, need-based irrigation was supplied as per the crop, and meteorological conditions. The nitrogen (N) was applied through FYM or vermicompost @10-15 t/ha along with rock phosphate @ 150 kg/ha and 200 kg/ha for rice and vegetables respectively (Table 1). For neutralizing the soil acidity, furrow application of lime (CaCO_3) @ 500 kg/ha was practiced especially for raised bed crops.

The rice crops were manually harvested in mid-October leaving ~ 30 cm from the ground surface from the designated main plot of $2 \times 2 = 4 \text{ m}^2$ area. The harvested samples were taken to the threshing floor for sun-drying and then weighed for biological (grain + straw) yields. Regarding, the okra, French bean, and pea picking of tender pods were started at 65 to 80 days and subsequent picking at a regular interval of 6-8 days. Similarly, potatoes and carrots were harvested in the mid-May once they attained maturity. Further, the system productivity in terms of rice-equivalent yield (REY) was computed as described by Das *et al.* (2017). The production efficiency (kg/ha/d) was calculated using the expression:

$$\text{SPE} = \frac{\text{System productivity (kg/ha)}}{365}$$

Further, the SYI was computed using the equation described by Singh *et al.* (1990):

$$\text{SYI} = (Y - \sigma) / Y_{\max} \dots \dots \text{(ii)}$$

Where Y = average yield obtained in a particular system in a year; σ = standard deviation, and Y_{\max} = Maximum yield obtained in a particular system in a year

Production costs and returns under raised and sunken beds were computed based on the prevailing market rates of 2022, and 2023. The input cost included rental values of land, seeds, organic pesticides, labor, FYM, rock phosphate, lime, etc. The system gross returns were calculated by summing the economic value of each crop, and net returns (as the difference between gross returns and production costs followed by conversion from Indian rupees (INR) to USD (\$) based on the exchange rate for different years.

The post-experimental soil samples were collected after the harvest of winter crops in 2023 from the upper soil layer (0-15 cm). Further, a composite soil sample was prepared by mixing the three sub-samples collected and air-dried samples followed by gentle grinding and passed through a 0.2 mm sieve for laboratory analysis. The soil pH was estimated in a 1:2.5 soil: water suspension using the procedure of Piper (1950). Further, the soil organic carbon (SOC) content was determined using Walkley and Black (1934) alkaline KMnO_4 oxidizable N 169.5 kg/ha (Subbiah and Asija, 1956), available phosphorus (P) by Bray and Kurtz No. 1 Method (Jackson, 1973), and 1 N NH_4OAc extractable K 275.3 kg/ha (Hanway and Heidel, 1952). The data generated from the experiment were subjected to analysis of variance (ANOVA) under a randomized block design setup to determine treatment effects (Gomez and Gomez, 1984). Tukey's honest significant difference test was employed to differentiate the mean effect of the treatments at a 5% significance level using

Table 1. Details of crop cultivars and agronomic practices adopted in the experiment

Crops	Variety	Sowing time	Harvesting	Spacing	Recommended N: P_2O_5 : K_2O * (kg/ha)
<i>Crops grown on raised beds</i>					
Potato	Kufri Jyoti	January 3 rd week	May 1 st week	60 cm × 20 cm	100:60:60
French bean	Naga Local	January 3 rd week	Periodic harvesting starting from 65 DAS (March 3 rd week to May 1 st week)	30 cm × 15 cm	60:60:40
Carrot	New Kuroda	January 3 rd week	April 4 th week	30 cm in a row	100:60:60
Okra	Pusa Sawani	July 1 st week	Periodic harvesting starting from 60 DAS (September 1 st week to November 1 st week)	30 cm × 15 cm	80:60:40
<i>Crops grown on sunken beds</i>					
Rice	Shahsarang-1, IR-64, Megha aromatic	June 2 nd week (Nursery) July 1 st week (transplanting)	Week of November (Shahsarang-1 and Lampnah), 3 rd week of 1 st October (IR-64 and Lampnah)	20 cm × 20 cm (transplanting)	80:60:40
Pea	Arkel	1 st -2 nd week of November	Periodic harvesting starting from 65 DAS (3 rd -4 th week of January to 3 rd week of February)	In between rice lines (20 cm spacing)	30:60:40

SAS 9.4 (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

The sunken beds are the areas lying in between raised beds and the runoff from the raised bed is collected there. In sunken beds, the rice varieties and nutrient management had a significant ($p < 0.05$) impact on the grain yield (Fig. 1). The highest rice yield was registered in Shasharang-1 (4.73 Mg/ha) followed by IR-64 (4.19 Mg/ha) and least in Megha aromatic (3.57 Mg/ha), which was 12.8% and 32.4% greater than the IR 64 and Megha aromatic, respectively. Similarly, among different NM practices, the highest grain yield was obtained in combined application FYM and VC (4.49 Mg/ha), but it remained statistically at par with vermicompost alone (4.18 Mg/ha), and lowest in FYM applied plots (3.82 Mg/ha). Further, the pod yield of pea was also recorded significantly ($p < 0.05$) highest in FYM+ VC (5.23 Mg/ha), followed by FYM (4.08 Mg/ha), and VC alone (3.57 Mg/ha) (Fig. 2).

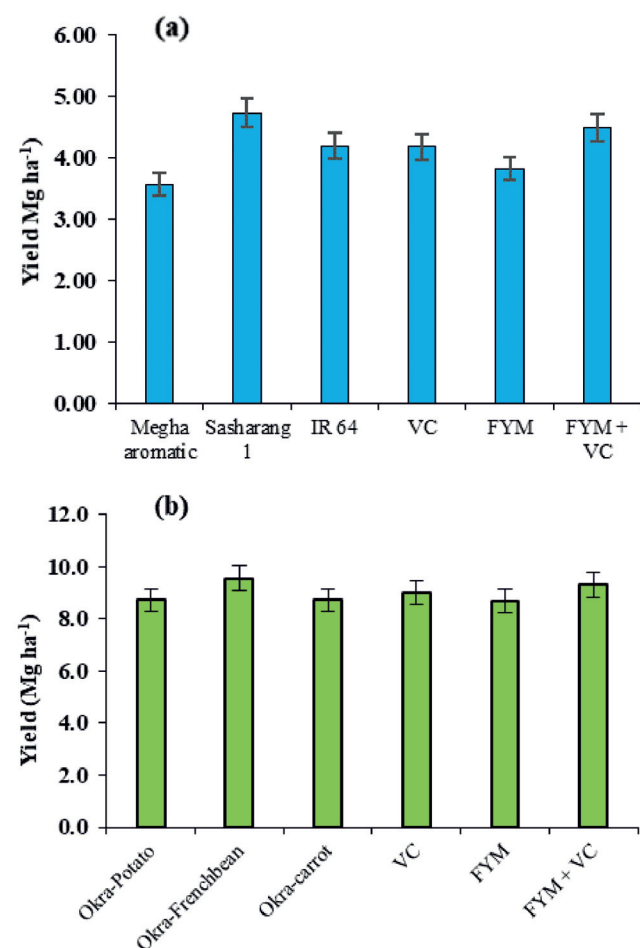


Fig. 1. Yield of rainy season crops *i.e.*, rice (a) and okra (b) as influenced by different varieties, cropping system, and nutrient management under raised and sunken beds (Mean of two years).

In the present study, the yield of crops during the pre-rainy season compared between stem/tuber (potato), root (carrot), and pod (French bean). The green pods are comparatively lighter in weight than the tuber and roots. This may be the reason that the potato and carrot yields were ~ 50% more than the French bean yield. While, in raised beds among the different cropping systems significantly ($p < 0.05$) greater fruit yield was obtained in okra-French bean (9.55 Mg/ha), which was to the tune of 9.52% than the okra-potato and okra-carrot. The conjoint use of FYM + VC had the highest economic yield of potato (17.0 Mg/ha) followed by vermicompost (16.19 Mg/ha), wherein it had 5.06% and 8.41% greater yield than the VC, and FYM alone respectively. Similarly, the French bean and carrot yield also followed a similar trend as the potato; wherein it produced 2.57 to 6.78%, and 1.84 to 9.16% greater yield than the vermicompost, and FYM alone (Fig. 1 and Fig. 2). In sunken beds, the variability in rice yield can be attributed to the genetic potential, and the adaptability to the climatic and ecological conditions (Layek *et al.*, 2018). Further, the higher yield of a pea, and rice in the combined use of FYM + VC might be ascribed to synchronized nutrient availability, and uptake, improves translocation of photosynthate, and crop growth as VC contains several plant growth-promoting substances (PGPR) such as hormones, auxins, vitamins, antibiotics, etc. (Choudhary and Suri, 2009). Similarly, in raised beds, the improvement in soil physico-chemical properties *viz.* aeration, soil moisture, and available N, P, and K through proper land configuration, and long-term application of organic manure might lead to higher vegetable yields (Gogoi *et al.*, 2022).

Concerning SP in sunken beds, among different cropping systems, the Shasharang-1-pea system had the highest system productivity (11.4 Mg/ha) but it remained statistically ($p < 0.05$) at par with IR 64-pea (10.8 Mg/ha) but significantly ($p < 0.05$) greater than Megha aromatic-pea (10.0 Mg/ha). Overall, the increment in SP in Shasharang-1-pea ranges from 5.55 to 14.0% than the others (Table 2). While, among nutrient management practices, the combined use of FYM, and VC had 23.0%, and 23.7% higher SP than the VC and FYM alone, respectively. Similarly, the trend of SPE and SYI was also similar to SP, wherein the Shasharang-1-pea system (31.3 and 0.75 kg/ha/d), and combined use of FYM + VC (33.7 and 0.81 kg/ha/d) had the highest SPE than the remaining treatments. In raised beds, the highest SP, SPE, and SYI were obtained in okra-carrot (24.7 Mg/ha; 67.7 kg/ha/d; and 0.93), and combined application of FYM + VC (21.9 Mg/ha; 60.0 kg/ha/d and 0.82) than the remaining cropping system, and nutrient management practices. The interaction effect in sunken bed showed the highest SP (13.25 Mg/ha), and SPE (36.31

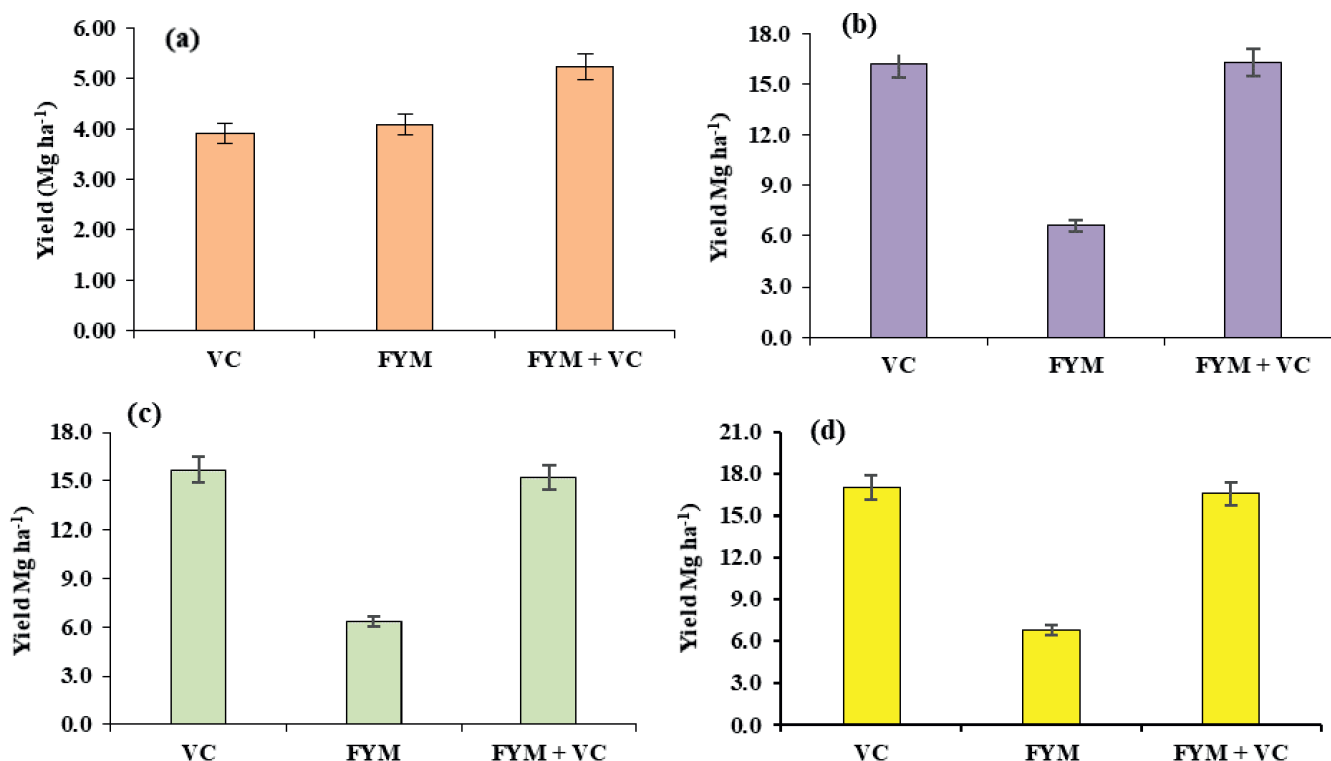


Fig. 2. Yield of winter season crops *i.e.*, pea (a), potato (b), French bean (c), and carrot (d) as influenced by different nutrient management under raised and sunken beds (Mean of two years).

Table 2. System productivity, production efficiency, and sustainable yield index as influenced by different varieties, cropping system, and nutrient management under raised and sunken beds (Mean of 2 years)

Treatments	Sunken bed			Raised bed			
	SP (Mg/ha)	SPE (kg/ha/d)	SYI	Treatments	SP (Mg/ha)	SPE (kg/ha/d)	SYI
<i>Cropping systems</i>							
CS ₁	10.0	27.4	0.66	CS ₁	20.9	57.3	0.77
CS ₂	11.4	31.3	0.75	CS ₂	17.7	48.6	0.67
CS ₃	10.8	29.7	0.71	CS ₃	24.7	67.7	0.93
SEm±	0.19	0.51	0.01	SEm±	0.54	1.49	0.02
LSD (P=0.05)	0.74	2.02	0.05	LSD (P=0.05)	2.14	5.86	0.08
<i>Nutrient management</i>							
NM ₁	10.0	27.5	0.67	NM ₁	21.23	58.1	0.80
NM ₂	9.94	27.2	0.65	NM ₂	20.31	55.6	0.75
NM ₃	12.3	33.7	0.81	NM ₃	21.90	60.0	0.82
SEm±	0.15	0.42	0.01	SEm±	0.22	0.61	0.01
LSD (P=0.05)	0.47	1.30	0.04	LSD (P=0.05)	0.69	1.88	0.03
Int.	NS	NS	*	Interaction	NS	NS	NS

CS₁, Megha-aromatic-pea; CS₂, shasharang-1-pea and CS₃, IR-64-pea and NM₁, vermi-compost; NM₂, FYM and NM₃, FYM + Vermicompost

kg/ha/d) in the Shasharang-1-pea system × combined use of FYM + VC (CS₂ × NM₃) followed by IR64-pea system × combined use of FYM + VC, and least in Megha aromatic-pea system × FYM. However, in a raised bed, the okra-carrot system × FYM + VC had the highest SP (25.84 Mg/ha), and SPE (70.8 kg/ha da/y) as compared to the remaining interacting treatments (Table 3). The higher

SP, SPE, and SYI in both raised and sunken beds might be attributed to greater crop yield, and higher market price of vegetables than the cereals; thereby contributing to greater equivalent yield. Similar results of higher SP in diversified rice-based systems were also conveyed by Nayak *et al.* (2012).

The adoption of permanent RSB with crop diversifica-

Table 3. Interaction effects of different cropping systems and nutrient management on system productivity (SP), and system production under raised and sunken beds (Mean of 2 years)

Treatments	System productivity (Mg/ha)	Production efficiency (kg/ha/d)	Treatments	System productivity (Mg/ha)	Production efficiency (kg/ha/d)
CS ₁ x NM ₁	9.53	26.1	CS ₁ x NM ₁	20.9	57.3
CS ₁ x NM ₂	8.94	24.5	CS ₁ x NM ₂	20.2	55.3
CS ₁ x NM ₃	11.5	31.7	CS ₁ x NM ₃	21.6	59.3
CS ₂ x NM ₁	10.7	29.4	CS ₂ x NM ₁	17.7	48.6
CS ₂ x NM ₂	10.3	28.2	CS ₂ x NM ₂	17.3	47.4
CS ₂ x NM ₃	13.2	36.3	CS ₂ x NM ₃	18.2	49.8
CS ₃ x NM ₁	9.88	27.0	CS ₃ x NM ₁	24.9	68.4
CS ₃ x NM ₂	10.5	28.9	CS ₃ x NM ₂	23.3	64.0
CS ₃ x NM ₃	12.1	33.2	CS ₃ x NM ₃	25.8	70.8
SEm±	0.27	0.73	SEm±	0.39	1.06
CD (P=0.05)	0.82	2.25	CD (P=0.05)	1.19	3.26

CS₁, Megha-aromatic-pea; CS₂, shasharng-1-pea and CS₃, IR-64-pea and NM₁, vermi-compost; NM₂, FYM and NM₃, FYM + Vermicompost

tion has the goal of enhancing the farmer's income to increase the system's productivity. The cost of cultivation for the rice-pea system was 855 USD/ha/y, while in nutrient management VC incurred the maximum cost of 914 USD/ha/y followed by combined application of FYM + VC (855 USD/ha/y) (Table 4). Further, the Shasharng-1-pea recorded the highest gross (2812 USD/ha/y), net return (1957 USD/ha/y) and SEE (5.36 USD/ha/d), which was to the tune of 5.04 to 14.0%; 7.40 to 21.5% and 31.7 to 38.6% than the IR-64-pea, and Megha aromatic-pea system. While, among nutrient management, the combined application of FYM + VC had the statistically ($p < 0.05$) gross (3027 USD/ha/y); net return (2173 USD/ha/y), and SEE (5.95 USD/ha/d). Similarly, in raised beds, the production cost was maximum in okra-potato (2276

USD/ha/y) followed by okra-carrot (2008 USD/ha/y) (Table 4). While, among nutrient management, the production cost was highest in VC (2479 USD/ha/y), and least in FYM plots (1473 USD/ha/y). Further, the highest gross (5833 USD/ha/y), net return (3825 USD/ha/y), and SEE (10.4 USD/ha/d) were registered in the okra-carrot followed by okra-potato and okra-French bean system. Likewise, the conjoint application of FYM + VC had 3.15 to 7.85%; 3.98 to 31.1%; and 3.89 to 31.0% greater gross, net return and SEE, respectively than the remaining treatments (Table 4). In sunken and raised beds, the significantly greater income, and economic efficiency were chiefly attributed to improved system productivity, strong market demand, and premium prices of vegetable crops viz. carrot, potato, French bean, okra, and pea (Babu *et al.*,

Table 4. Economics of different cropping systems and nutrient management under raised and sunken beds (Mean of 2 years)

Treatment	Sunken bed				Treatments	Raised bed			
	COC (\$/ha/y)	GR (\$/ha/y)	NR (\$/ha/y)	SEE (\$/ha/d)		COC (\$/ha/y)	GR (\$/ha/y)	NR (\$/ha/y)	SEE (\$/ha/d)
<i>Cropping systems</i>									
CS ₁	855	2465	1610	4.41	CS ₁	2276	4939	2663	7.30
CS ₂	855	2812	1957	5.36	CS ₂	1644	4189	2546	6.97
CS ₃	855	2677	1822	4.99	CS ₃	2008	5833	3825	10.4
SEm±	-	43.88	43.88	0.12	SEm±	-	128.5	128.5	0.35
CD (P=0.05)	-	172.2	172.2	0.47	LSD (P=0.05)	-	504.4	504.4	1.38
<i>Nutrient management</i>									
NM ₁	914	2481	1567	4.29	NM ₁	2479	5007	2528	6.93
NM ₂	796	2446	1650	4.52	NM ₂	1473	4789	3316	9.08
NM ₃	855	3027	2173	5.95	NM ₃	1976	5165	3189	8.74
SEm±	-	35.91	35.91	0.10	SEm±	-	52.61	52.61	0.14
CD (P=0.05)	-	110.6	110.6	0.30	LSD (P=0.05)	-	162.0	162.0	0.44
Int.	-	NS	NS	NS	Int	-	NS	NS	NS

Note: Sunken bed: CS₁, Megha-aromatic-pea; CS₂, shasharng-1-pea and CS₃, IR-64-pea and NM₁, vermi-compost; NM₂, FYM and NM₃, FYM + Vermicompost

2020), along with reduced cost of cultivation in integrated supply of FYM + VC than the remaining treatments.

In sunken beds, the soil pH varies from 5.13-5.19 (Table 5) under different cropping systems, while the application of VC had the highest pH (5.17) and the least in FYM plots (5.14). Further, the highest SOC content was registered in the Shasharang-1-pea system (26.6 g/kg), and FYM treated plots (26.73 g/kg) but both remain statistically ($p < 0.05$) at par with IR64-pea system (26.4 g/kg) and combined use of FYM + VC (26.5 g/kg). On average the increment in SOC under the Shasharang-1-pea system, and FYM was to the tune of 0.50 to 4.20% and 0.86 to 5.36%, respectively than the other treatments. The available N was registered maximum in Megha aromatic-pea (272.0 kg/ha) and FYM treated plot (271.1 kg/ha). Like N a similar trend of available P, and K was recorded among

different cropping systems, but it was the combined use of FYM + VC that registered the highest values [11.1 kg/ha (P) and 267.1 kg/ha (K)] than the other practices. In raised beds, among different cropping systems, and nutrient management the soil pH varied between 5.13 to 5.17, and 5.15- 5.17, respectively (Table 6). Further, the highest SOC content was registered in the okra-French bean system (22.6 g/kg), and FYM treated plot (22.7 g/kg), but it remained at par with the okra-potato system (22.5 g/kg) and combined use of FYM + VC and least in okra-carrot system (21.7 g/kg), and VC applied plot (21.5 g/kg). Further, the highest available N (261.6 kg/ha), P (11.4 kg/ha), and K (266.9 kg/ha) was recorded in okra-French bean system, while among nutrient management practices, the highest Available N (256.3 kg/ha) was registered in FYM treated plot, in contrast the available P (11.3 kg/ha), and K

Table 5. Impact of different varieties and nutrient management on different soil properties in sunken beds (Mean of 2 years)

Treatment	pH	SOC (g/kg)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
<i>Cropping systems</i>					
CS ₁	5.19	25.5	272.0	11.1	266.5
CS ₂	5.16	26.6	262.6	10.7	257.5
CS ₃	5.13	26.4	270.1	11.0	264.3
SEm±	0.10	0.13	1.26	0.11	3.19
CD (P=0.05)	NS	0.51	4.94	NS	NS
<i>Nutrient management</i>					
NM ₁	5.17	25.3	264.1	10.7	256.3
NM ₂	5.14	26.7	271.1	11.0	264.9
NM ₃	5.16	26.5	269.5	11.1	267.1
SEm±	0.10	0.20	1.53	0.11	2.66
CD (P=0.05)	NS	0.63	4.73	0.34	8.20
Int.	NS	NS	NS	NS	NS

Sunken bed: CS₁, Megha-aromatic-pea; CS₂, shashrang-1-pea and CS₃, IR-64-pea and NM₁, vermi-compost; NM₂, FYM and NM₃, FYM + Vermicompost

Table 6. Impact of different cropping and nutrient management on different soil properties in raisedbeds (Mean of 2 years)

Treatment	pH	SOC (g/kg)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
<i>Cropping systems</i>					
CS ₁	5.17	22.5	245.1	11.1	256.9
CS ₂	5.17	22.6	261.6	11.4	266.9
CS ₃	5.15	21.7	250.2	10.7	257.5
SEm±	0.02	0.11	2.19	0.07	3.19
CD (P=0.05)	NS	0.44	8.59	0.27	NS
<i>Nutrient management</i>					
NM ₁	5.16	21.5	249.5	10.8	254.0
NM ₂	5.15	22.7	256.3	11.2	262.5
NM ₃	5.17	22.5	251.1	11.3	264.8
SEm±	0.04	0.17	1.50	0.11	2.66
CD (P=0.05)	NS	0.54	4.62	0.34	8.20
Int.	NS	NS	NS	NS	NS

Raised bed: CS₁, okra-potato; CS₂, okra-frenchbean, and CS₃, okra-carrot and NM₁, Vermi-compost; NM₂, FYM and NM₃, FYM + Vermicompost

(264.8 kg/ha) was significantly ($p < 0.05$) highest in combined use of FYM + VC followed by FYM, and VC alone. In sunken beds, the improvement in soil *pH* with the use of VC might be due to its slightly higher pH relative to FYM. Further, the higher SOC content may be ascribed to an increase in soil organic matter (SOM) resulting from the long-term application of organic amendments, lesser oxidation of organic matter due to continuous submergence; and recycling of anchored crop residue, and weed biomass (Layek *et al.*, 2018). Similarly, the higher N, P, and K content might be due to the inclusion of pea as it fixes atmospheric N and releases organic acids such as citric and malic thereby promoting sustained soil health (Das *et al.*, 2013). Further, in raised beds, the greater SOC, N, P, and K in the okra-French bean system along with the application of organic manures might be due to improvement in soil physical conditions (Layek *et al.*, 2014), the addition of leaf litter having narrow C/N ratios, and enhanced nutrient pools through nitrogen fixation and recovery of insoluble phosphorus (Shen *et al.*, 2002).

Adoptions of a permanent RSB system of cultivation with proper cropping sequence in rice paddies in the lowlands of the eastern Himalayas of India will not only increase the production and productivity of vegetables and cereal crops but also enhance cropping intensity, employment, and income substantially. The vegetable-based system, such as okra-potato and okra-carrot in raised beds and the rice-pea system in sunken beds, provides a greater net return and economic efficiency, thereby sustaining the livelihood of the farmers. The study also indicated that French bean okra under a raised bed and rice pea under a sunken bed system can increase SOC concentrations and stocks over time. Further, the long-term application of organic amendments improves and sustains soil health.

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