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Economic and sustainable appraisal of organic growers through no-till garden pea (*Pisum sativum*) under rice (*Oryza sativa*)-fallow

MANOJ KUMAR[1], RAGHAVENDRA SINGH[1]*, R K AVASTHE[2], SUBHASH BABU[3], P K PATHAK[1] and J K SINGH[1]

Krishi Vigyan Kendra, East Sikkim, Ranipool, Sikkim 737 135, India

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ABSTRACT

Low productivity and profitability are the major constraints of organic growers due to continuous rice (*Oryza sativa* L.) -fallow practice in Sikkim Himalayas. No-till garden pea (*Pisum sativum* L.) cultivation in rice-fallow may be an option for enhancing the productivity and profitability of the farmers in this region. Hence, to test the feasibility of no-till garden pea cultivation in the rice-fallow area, a frontline demonstration was carried out by the ICAR-Krishi Vigyan Kendra (KVK), East Sikkim during 2017–20 for increasing productivity, profitability and sustainability of the rice-fallow. Results indicated that rice yield was ranged from 20.8–22.6 q/ha during three years. The three-year mean of rice equivalent yield (REY) was recorded 107.23 q/ha and 21.6 q/ha under rice-garden pea and rice-fallow system, respectively. Higher production efficiency (39.87 kg/ha/day), economic efficiency (503.80 ₹/ha/day) and land-use efficiency (73.51%) were recorded in the rice-garden pea system compared to rice-fallow. Soil organic carbon (SOC) was 7.20% higher under the rice-garden pea system after 3 cropping cycles. The average net return and benefit-cost ratio was recorded ₹135091/ha, ₹19793/ha, and 2.83, 1.83 under rice-garden pea and rice-fallow, respectively. Higher output energy, net energy and energy productivity were recorded in rice-garden pea as compared to rice-fallow. Hence, it may be concluded that the inclusion of garden pea is an option for improving the productivity, profitability, and soil health and energy use efficiency under Sikkim Himalayas.

Keywords: Economics, Garden pea, No-till, Organic, Soil properties

In India, a major chunk of area is kept fallow [11.7 million hectares (mha)] during winter (*rabi*) season after rice (*Oryza sativa* L.) crop due to various (biotic, abiotic, and socio-economic) constraints (Kumar *et al.* 2020). Sikkim's cropping intensity is very low (118%) due to monocropping (Avasthe *et al.* 2019). Due to severe moisture scarcity, farmers kept rice fields fallow after harvesting in *rabi* season. Hence, most of the area remains fallow (Babu *et al.* 2020). Cultivation of garden pea (*Pisum sativum* L.) under no-till in rice-fallow may be an option to get the economic benefits (Singh *et al.* 2016). Garden pea inclusion in rice-fallow is more advantageous than monocropping in terms of productivity, profitability and energy use efficiency (Singh *et al.* 2015). In India, garden pea is grown in 540.48 thousand ha with 5.42 million tonnes production and of 10.03 tonnes/ha productivity (Indian Horticulture Database 2018). The area under garden pea cultivation in Sikkim is 4100 ha with a production of 17700 tonnes and productivity of 4.32 tonnes/ha, which is far below than national productivity (Indian Horticulture Database 2018). Thus, there is potential for growth of garden pea in rice-fallow areas under no-tillage.

No-till requires very little soil disturbance with preceding crops residues on soil surface as a mulch to conserve the soil and water (Tripathi *et al.* 2016). Compared to conventional farming, no-tillage technology enabled farmers to increase returns while saving critical inputs (Bhushan *et al.* 2007). Hence, this promising technology may be an alternate for generating higher farm income and saving of resources. Advantages of no-tillage include previous crop residue retention, direct sowing, improves soil carbon sequestration, reduces GHG emissions and reduces fossil fuel use. Thus, no-till has a great potential for adopting small and marginal holders under changing climatic conditions (Behera *et al.* 2014). It seems to be an appropriate strategy for adapting agricultural production systems to climate change by conserving water and soil resources (Singh *et al.* 2015). Among the various performance indicators of crop, energy analysis is playing an important role. The productivity of crop is inversely

[1]Krishi Vigyan Kendra, East Sikkim, Ranipool, Sikkim; [2]ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok; [3]ICAR- Indian Agricultural Research Institute, New Delhi. *Corresponding author e-mail: raghavenupc@gmail.com

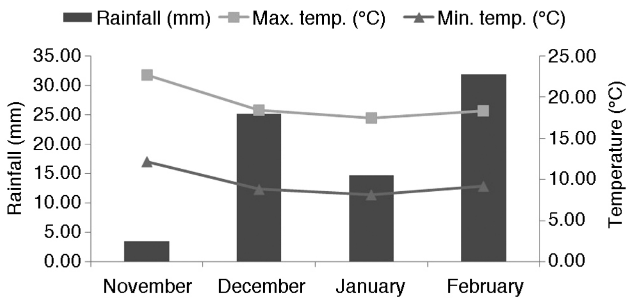

Fig 1 Mean monthly weather parameter during the experimental period (2017–2020).

related to energy use efficiency (Tuti and Das 2011). In view of the above points, Krishi Vigyan Kendra took the initiative and conducted frontline demonstration (FLD) on no-till garden pea cultivation in rice-fallow.

MATERIALS AND METHODS

Frontline demonstrations (FLDs) were conducted by the ICAR-Krishi Vigyan Kendra (KVK), East Sikkim, Ranipool on no-till garden pea cultivation in rice-fallow under rice based system of Sikkim at farmers field during *rabi* for three consecutive years from 2017–18 to 2019–20 at different villages, viz. Nandok, Timpyem, Sajong and Lingtam in East Sikkim. The total rainfall received during cropping period was 17.42 mm, 98.60 mm and 108.8 mm in 2017–18 2018–19 and 2019–20, respectively (Fig 1). Maximum temperature was 23.3°C, 21.7°C and 22.9°C while the minimum temperature was 9.6°C, 6.4°C and 6.7°C during 2017–18, 2018–19 and 2019–20. Garden pea growers (20 nos.) from the entire village were selected for demonstration of no-till cultivation in rice-fallow. The area under each demonstration was ~0.20 ha. Recommended organic management practices (FYM @2.5 t/ha + vermicompost @1.0 t/ha + neem cake @0.5 t/ha + dolomite @0.5 t/ha) were applied before sowing of garden pea under no-till system.

Rice was harvested 20 cm above the ground surface in the month of November in each year. Immediately after rice harvest, garden pea was sown under no-till. A narrow furrow was opened at 30 cm apart on soil surface with spade or locally made wooden row marker, applied all the organic nutrients. Seed was placed after manuring at a spacing of 15 cm plant to plant. The surface layer of soil should remain sufficiently moist to allow good germination. There are two critical stages such as pre-flowering and pod formation stage where irrigation was applied to ensure good crop stands. Two hand weeding was done at 15 and 35 days after sowing. The yield of rice and vegetable pea were recorded at each demonstration and converted the yield into q/ha. The other parameter like rice equivalent yield (REY), production efficiency, economic efficiency, net returns, B:C ratio and energetic were calculated. The commodity input and output prices that prevailed during the experiment for the three years of demonstration were used to calculate the cost of cultivation. The gross income, net income and benefit cost ratio was calculated by the formula given by Singh *et al.* (2016). The soil samples were collected from 0–15 cm depth for analyzing the N, P and K status and soil organic carbon. Rice equivalent yield (REY) and land use efficiency (LUE) were calculated as:

$$\text{REY} = \text{Yield of rice (first crop)} + \text{garden pea yield} \times \text{price of garden pea / price of rice}$$

$$\text{Land use efficiency (LUE)} = \frac{\text{Total number of days occupied by different crop}}{365} \times 100$$

System productivity (kg/ha/day) was calculated by dividing production of sequence by total duration of crop sequences and system profitability in terms of ₹/ha/day was obtained by net returns of the sequence divided by total duration of crop sequences (Kumar *et al.* 2017).

Input and output of energy were assessed by the different inputs used in terms of labour, farmyard manure, seed etc. and output in terms of grain and straw yield multiplied with their corresponding energy values as described by Yadav *et al.* (2017). Total sum of energy equivalents for all inputs was calculated as total energy input and energy output [yields of grain and by-product (straw/leaves/stalk)] from the product (grain) was calculated by multiplying yield and its corresponding energy equivalent. Energy outputs from by-product were calculated by multiplying yield of by-product and its corresponding energy equivalent. Other energy parameters were calculated as:

$$\text{Net energy return} = \text{Gross output energy} - \text{Total input energy}$$

$$\text{Energy profitability (PE)} = \frac{\text{Net energy (MJ/ha)}}{\text{Input energy (MJ/ha)}}$$

$$\text{Energy productivity (EP)} = \frac{\text{Crop economic yield (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Energy use efficiency (EUE)} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Energy output efficiency} = \frac{\text{Energy output (MJ/ha)}}{\text{Duration of the system (days)}}$$

Economics and rice equivalent was calculated at prevailing wholesale market price during all the year for different commodities. The mean data from all the observations collected over three years were pooled and statistically analysed using F-test (Panse and Sukhatme 1984). The t-test was used to see the significance of the treatments. Differences of mean between treatments that were greater than respective least significant different (LSD) values were considered as significant difference at 5% level of probability (P=0.05).

RESULTS AND DISCUSSION

Production efficiency: Rice grain yield was ranged 20.9.8–22.6 q/ha under rice-garden pea and rice-fallow system. Maximum garden pea yield was recorded 59.40

Table 1 Yield of rice and vegetable pea cultivation in rice-fallow

	Rice yield (q/ha)	Vegetable pea yield (q/ha)	REY of vegetable pea (q/ha)	System REY (q/ha)
2017–18	20.90 ± 1.24	59.40 + 3.60	96.53 ± 5.85	117.43 ± 6.11
2018–19	22.60 ± 1.57	48.30 + 2.75	78.49 ± 4.46	101.93 ± 4.04
2019–20	21.40 ± 1.19	49.70 + 2.56	80.93 ± 4.15	102.33 ± 4.48
Mean	21.60	52.46	85.32	107.23

REY, Rice equivalent yield.

q/ha in the year 2017–18 followed by 49.70 q/ha during 2019–20 and minimum 48.30 q/ha during 2018–19 (Table 1) with mean yield of three years (52.46 q/ha). Rice equivalent yield (REY) of vegetable pea was 96.53 q/ha, 78.49 q/ha and 80.93 q/ha in 2017–18, 2018–19 and 2019–20, respectively and mean REY of three years was 85.32 q/ha (Table 1). System REY was recorded 117.43, 101.93 and 102.33 q/ha during the year 2017–18, 2018–19 and 2019–20, respectively under rice-garden pea cropping system. Whereas, REY was 20.9, 22.6, 21.4 q/ha during 2017–18, 2018–19 and 2019–20 respectively in rice-fallow system. Maximum mean (3 years) REY was recorded 107.43 q/ha in rice-garden pea system than rice-fallow (21.6 q/ha) and was 397.6% higher than rice-fallow. Kumar *et al.* (2019a) reported that maximum productivity was found with rice-cabbage system. Maximum production efficiency (PE) was recorded 44.15, 37.58 and 37.90 kg/ha/day during 2017–18, 2018–19 and 2019–20, respectively in rice-garden pea system than rice-fallow. The inclusion of garden pea in rice-fallow might be the reason for higher productivity, profitability and production efficiency in rice-garden pea system. Minimum disturbance of soils under no-till seems to conserve the higher soil moisture which provides favourable condition for growth and development of garden pea after rice crop resulting in higher productivity. Higher crop productivity under no-till system over conventional tillage across different ecologies has been reported by many researchers (Yadav *et al.* 2020, Singh *et al.* 2021b). Similar higher system productivity under maize-pea system was reported by Singh *et al.* (2021a). Kumar *et al.* (2019b) also reported that rice-green gram system enhanced the system profitability and production efficiency by 126% and 307%, respectively than rice fallow.

Land use efficiency (LUE): LUE was recorded 72.88%, 73.70% and 73.97% higher under rice-garden pea during 2017–18, 2018–19 and 2019–20, respectively as compared to rice-fallow (Table 2). Mean land use efficiency of three years was recorded 73.51% in rice-vegetable pea as compared to 39.47% in rice-fallow. This might be due to inclusion of garden pea just after rice harvest and utilised land efficiently, which enhanced the profitability with more employment generation during the system. Kumar *et al.* (2020) reported that intensification through short duration vegetables/pulses in cropping system increases the LUE. This was also supported by Kumar *et al.* (2019a). According to Sharma *et al.* (2004), intensification of vegetables and legumes crops can increase the land use efficiency by 46–78%.

Economic appraisal: The economic indicator clearly demonstrated that net returns from the rice-garden pea were substantially higher than the rice-fallow. The net return was ranged ₹18250–21450/ha in rice-fallow, while it was ₹123375–156050/ha with rice-vegetable pea system during the three years of demonstration (Table 2). Addition of garden pea in rice-fallow system added the additional yield compared to rice alone in system mode. This was main reason for higher net returns in rice-garden pea over rice-fallow in the study. The benefit : cost (B:C) ratio was recorded 1.79, 1.90, 1.80 in rice-fallow and 2.98, 2.57, 2.60 in rice-vegetable pea system during 2017–18, 2018–19 and 2019–20, respectively. This might be due to that recommended practices produced higher yield than farmer's practice. Similar result has been reported earlier by Singh *et al.* (2012). Economic efficiency was recorded 586.7, 458.65 and 466.07 ₹/ha/day under rice-garden pea system and 130.85, 148.96 and 132.53 ₹/ha/day in rice-fallow during 2017–18, 2018–19 and 2019–20, respectively.

Table 2 Economics and efficiency of rice-based cropping system

	Net income (₹/ha)		B:C ratio		Production efficiency (kg/ha/day)		Economic efficiency (₹/ha/day)		Land use efficiency (%)	
	Rice-fallow	Rice-garden pea	Rice-fallow	Rice-garden pea	Rice-fallow	Rice-garden pea	Rice-fallow	Rice-garden pea	Rice-fallow	Rice-vegetable pea
2017–18	18250 ± 2242	156050 ± 11886	1.79 ± 0.09	2.98 ± 0.14	14.65 ± 0.94	44.15 ± 2.35	128.52 ± 16.28	586.70 ± 45.26	38.90 ± 0.32	72.88 ± 0.37
2018–19	21450 ± 3019	123375 ± 7890	1.90 ± 0.13	2.57 ± 0.10	15.70 ± 1.19	37.58 ± 1.49	148.96 + 22.10	458.65 ± 29.30	39.45 ± 0.50	73.70 ± 0.29
2019–20	19054 ± 2207	125850 ± 8688	1.80 ± 0.09	2.60 ± 0.11	14.66 ± 0.85	37.90 ± 1.60	130.48 ± 15.46	466.07 ± 31.38	40.0 ± 0.27	73.97 ± 0.32
Mean	19793.3	135091.7	-	-	15.02	39.87	137.44	503.80	39.47	73.51

Higher efficiency under rice-garden pea might be due to inclusion of second crop (garden pea) in rice-fallow, which enhanced the productivity as well as income compared to rice alone. Kalita *et al.* (2018) reported that the higher economic efficiency was obtained in rice-cabbage (₹668.37/ha/day) and rice-tomato (₹998.20/ha/day) than rice-fallow (₹195.17/ha/day) in Assam.

Soil health: Soil health is the indicator of production capacity of soil under proper scientific management. In this study, soil organic carbon (SOC), available N, P and K in rice based system was analysed and presented in the Table 3. The soil organic carbon value was recorded 1.28% and 1.35% in rice-fallow and rice-garden pea, respectively as compared to the initial value (1.26%) after three cropping cycle. The SOC was 7.20% and 1.26% higher under rice-garden pea and rice-fallow after three cropping cycle as compared to the initial value. Retention of rice as well as garden pea residue following their subsequent decomposition with minimum soil disturbance under no-till plays an important role for soil organic carbon improvement in surface soil. While under rice-fallow where proper tillage is adopted breaks soil aggregates and subsequently exposes the stored carbon in macro and micro aggregates to a microorganism for further decomposition and mineralization processes resulting in low soil organic carbon (Yadav *et al.* 2019). Hence, the no-till practices favoured the accumulation of SOC which may enhance the nutrients accumulation and mobilization (Singh *et al.* 2021a). The accumulation of higher SOC under this experiment was due to more root biomass inclusion through garden pea in rice-based system. No-till favoured the slow decomposition of organic matter and facilitated the proper supply of available nutrients to the crop (Das *et al.* 2017). Higher available N, P and K in soil was found (334.49, 16.10, 348.42 kg/ha, respectively) with rice-garden pea than rice-fallow (311.09, 15.02, 336.82 kg/ha, respectively) and also 9.4, 16.8, 4.77% in rice-garden pea and 1.80, 8.29, 1.28 in rice-fallow higher than the initial value. This might be due to addition of garden pea in rice-fallow and which might have enhanced microbial activities due to symbiotic N-fixation and addition of biomass to soil (Das *et al.* 2017).

Energetics: Energy analysis is a recent tool to know the efficiency of the different treatment and respective treatment is considered more efficient when it produces higher output energy and requires less input energy. The highest input energy was 11198.3 MJ/ha with rice-vegetable pea system than rice-fallow (6175.3 MJ/ha). The output energy was recorded 30.56% higher in rice-garden pea than the rice-fallow (Table 3). Higher net energy and energy productivity were recorded 86007.3 MJ/ha and 95.76 kg/MJ in rice-vegetable pea system than rice-fallow. Whereas, the energy use efficiency (12.06 MJ/ha), energy profitability (11.06) and specific energy (34.70 MJ/t) were higher in rice-fallow. This indicates that the maximum energy is needed to produce a unit of output under rice-fallow, while highest amount of product obtained per unit of energy invested in rice-vegetable system (Kumar *et al.* 2019a).

Table 3 Soil properties and energetics of rice-based cropping system after 3 cropping cycles

	Initial				Final				Input energy (MJ/ha)	Output energy (MJ/ha)	Energy use efficiency (MJ/ha)	Net energy (MJ/ha)	Energy productivity (kg/MJ)	Energy profitability	Specific energy (MJ/t)
	SOC (%)	Avail. N (kg/ha)	Avail. P (kg/ha)	Avail. K (kg/ha)	SOC (%)	Avail. N (kg/ha)	Avail. P (kg/ha)	Avail. K (kg/ha)							
Rice-fallow	1.263 ± 0.06	305.58 ± 12.37	13.87 ± 1.55	332.54 ± 10.98	1.279 ± 0.07	311.09 ± 10.39	15.02 ± 1.59	336.82 ± 9.25	6175.3	74452	12.06	68276.7	34.98	11.06	34.47
Rice-garden pea					1.354 ± 0.10	334.49 ± 13.10	16.10 ± 2.31	348.42 ± 8.90	11198.3	97205.6	8.68	86007.3	95.76	7.68	9.07

Avail, Available; SOC, Soil organic carbon.

Thus, the cultivation of garden pea under no-tillage in rice-fallow system in Sikkim condition not only increased the productivity, profitability but also enhanced the soil health. No-tillage cultivation practices is most suitable for cost effectiveness, labour saving, energy efficient and getting higher net income with efficient utilization of locally available resources under organically managed conditions of Sikkim.

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