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Impact of seven years of organic farming on soil and produce quality and crop yields in eastern Himalayas, India

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ABSTRACT

Low use of chemicals in agriculture, plentiful availability of biomass and manure and favorable climatic conditions offer the opportunity for organic farming in eastern Himalayan region of India. Thus, field experiments were conducted in seven consecutive years from 2005 - 06 to 2011 -12 under a raised and sunken bed (RSB) land configuration (0.3–0.4 m height, 2 m width, 7 m length) in lowland at Meghalaya (950 m above sea level), India. The RSBs were constructed to facilitate drainage and accommodate vegetables in lowland conditions. The objectives of the study were (i) to identify suitable crops and cropping sequences for organic food production, and (ii) to assess long term impacts of organic farming on soil and produce quality. Rice (*Oryza sativa* L.) – vegetable sequences on raised beds and rice (varieties) – fallow (no crop) sequences on sunken beds were assessed under four farming practices in fixed plots. The four farming practices were control (only in-situ recycling of 2/3rd crop residues), organic (farmyard manure and rock phosphates), inorganic (mineral fertilizer) and integrated farming [50/50 organic and inorganic fertilizer sources (INF)]. Results indicated that seven-year average productivity of tomato (*Solanum lycopersicum* L.) and carrot (*Daucus carota* L.) under organic (22.1, and 10.1 Mg ha^{-1}, respectively) and INF (21.9, and 10.4 Mg ha^{-1}, respectively) were significantly higher than both inorganic (17.6, and 7.1 Mg ha^{-1}, respectively) and control (3.77, and 3.1 Mg ha^{-1}, respectively). However, yields of potato (*Solanum tuberosum* L.) and French bean (*Phaseolus vulgaris* L.) were the highest under INF (14.4 and 8.7 Mg ha^{-1}, respectively) followed by organic (13.9 and 7.5 Mg ha^{-1}, respectively). Considering farming practices, INF (3.99 Mg ha^{-1}), organic (3.85 Mg ha^{-1}) and inorganic (3.81 Mg ha^{-1}) had the similar rice productivity in sunken beds but all had significantly higher yield than that of control. After seven years, the soil available N on raised and sunken beds under organic farming was 13.3 and 4.36% higher than that under inorganic and 20.8 and 18.2% higher than that under control, respectively. Soil microbial biomass carbon was significantly higher under organic raised (177.9 μg g^{-1} dry soil) and sunken beds (146.77 μg g^{-1} dry soil) than that of other farming practices. Most of the quality parameters of tomato (lycopene content, total sugar, total soluble solids) and carrot (total soluble solids, ascorbic acid, beta carotene) were superior under organic farming followed by INF. Combining all these long-term results, the study strongly suggests several benefits of organic farming for sustainable productivity and improved soil and produce quality under eastern Himalayan condition.

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1. Introduction

Increase in awareness and concerns about the negative environmental and health impacts of synthetic chemicals (fertilizers, pesticides, livestock feed additives etc.) in agriculture have been major drivers for the increase in consumer demand for organic foods (Baranski et al., 2014). Organically grown produce are considered environmentally safer and more nutritious than conventionally grown produce (Williams and Hammitt, 2001). Thus, there is need for major change in the global food production system, while meeting challenges of feeding a growing population and minimizing environmental concerns (Foley et al., 2011).

Continuous and increased use of chemical fertilizers leads to several detrimental effects on soil and water quality with reduction

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in soil productivity (Baishya, 2015). Long term field experiments indicated a declining trend in productivity and degradation of soil resource due to intensified cropping with constant fertilizer inputs without addition of manure (Cassman and Pingali, 1995).

On the other hand, organic farming has potential benefits in comparison to conventional farming in promoting soil structure formation (Pulleman et al., 2003), enhancing soil biodiversity (Tu et al., 2006), protecting environment (IFOAM, 1998), improving soil quality (Patel et al., 2015), food quality and safety (Giles, 2004) and ensuring premium price (Gopinath et al., 2008). Reported increase in crop yields during the first few years of organic farming have been attributed to gradual improvements in soil properties, such as the capacity of the soil microbial community to mineralize N (Martini et al., 2004). Thus, organic production systems have the potential to achieve sustainability of agricultural systems (Van Diepeningen et al., 2006).

Emerging evidences also indicate that soil fertility management integrating combination of organic and inorganic fertilizer is a sustainable approach to overcome several soil fertility constraints (Abedi et al., 2010). Many long-term experiments comparing conventional and organic practices have documented increased soil organic matter (SOM) and soil organic carbon (SOC) accumulation in organically managed soils (Lotter, 2003). Although the benefits of organic farming are overwhelming, some uncertainties still exists. For an example, no differences in soil microbial biodiversity was observed (Lawlor et al., 2000; Franke-Snyder et al., 2001) between organically or conventionally managed soils. Yet, combined organic/inorganic fertilization enhanced C storage in soils (Pan et al., 2009), and improved available N, P, K and S (Bhattacharya et al., 2008).

In view of growing demand for organic food products worldwide, the North Eastern Region of India (NER, geographical area 26.2 M ha), in Eastern Himalayas have vast opportunity to emerge as major suppliers of organic products (Sanwal et al., 2007). The climate (high rainfall, cold winter and hot humid summer), soil type and management practices in NER are unique. The region has a number of advantages for organic food production such as minimal use of fertilizer (12 kg ha^{-1} in hills) and pesticides, plentiful availability of plant biomass (weeds, shrubs and forest litter) and reasonable amount of organic manure (47 million tons) and diverse climatic conditions for growing a wide range of crops. Additionally, relatively high SOC concentrations (15.0–35.0 g kg^{-1}) offer the opportunity for moving towards scientific organic farming (Bujarbaruah, 2004; Patel et al., 2015).

Monocropping of rice (*Oryza sativa* L.) is the prevalent practice in hills especially under valley land conditions. Cultivation of a second rice crop in valleys and lowlands after rainy season is not possible mainly due to early onset of winter which causes spikelet sterility (Munda et al., 2010). Diversification and intensification of monocropped rice system to increase productivity per unit resource is very pertinent to enhance income (Das et al., 2014a). Even in winter season, the water table in valley land remains high mainly because of continuous seepage from surrounding hillocks. Innovative land configuration such as raised and sunken bed (RSB) technology provides opportunity to include vegetables in rice based cropping system in high rainfall areas and lowlands and thus, increase productivity and financial gain. Raised beds (30–45 cm height and appropriate width) are suitable for cultivation of vegetables in rice paddy areas with adequate facilities for draining excess water, while in such systems sunken areas are used for cultivation of rice (Das et al., 2014a). The RSB land configuration in high rainfall region increases cropping intensity by creating favorable soil moisture regime such as moisture conservation by inter-plot water harvest during dry season (Mishra and Saha, 2007). Land configuration through RSB improves the soil physical condition, aeration, and water regime for crop growth and productivity (Das et al., 2014a). Benefit cost ratio of 1.22–1.57 due to RSBs (rice-vegetables) as compared to 0.81 for monocropping of rice has been reported from high rainfall areas of North East Indian Himalayas (Saha and Ghosh, 2010). The identification of well-designed crop rotations (crops with different rooting habits, different nutrient need, growth duration, etc.) is key to the success of organic production systems (Patel et al., 2015), however, the response of various crops may be different to diverse sources of nutrient and other farming practices. Thus, suitable cropping sequences are to be identified for stability in production and improving soil quality. Yet, information on comparative performances of crops and cropping systems under organic, inorganic and integrated farming (INF) practices on soil health, productivity and produce quality are scanty, particularly for hill ecosystems.

Additionally, in hill ecosystems of eastern Himalayas, use of agrochemicals is negligible and cultivation is mainly done on inherent soil fertility or with very low level of organic manure application (about 5 Mg ha^{-1} once in 2 years) causing low productivity (Das et al., 2014b). Under such situation, adoption of organic farming through identification of efficient cropping systems, recycling of on-farm biomass, use of adequate quantity of organic manure to supplement crop nutrient requirement along with use of bio-pesticides for pest management would enhance productivity, and financial gain to hill farmers (Patel et al., 2015).

Thus, a seven year field study was conducted in mid altitude of subtropical Meghalaya (950 m a.s.l.), India, to evaluate the impact of organic, inorganic and INF farming practices on performance of various cropping systems, soil and produce quality parameters. The primary hypothesis tested was that continuous organic farming would improve soil health, productivity and produce quality due to consequent improvement of soil physico-chemial and biological properties compared to those of conventional (chemical based) farming on a long-term basis. The second hypothesis tested was that varied cropping sequences responds to various farming practices (organic, inorganic, INF) differently based on the type of crops grown, their nutrient (other resources) demand, and other management practices.

The novelty of the study is that complete organic, inorganic and INF farming practices i.e., nutrient, pest and disease management etc. were all taken into consideration and RSB land configuration as an innovative approach in high rainfall hill ecosystem was integrated in this long-term study, which has not been tested in the Himalayan ecosystem yet.

2. Materials and methods

Long-term (seven years: 2005–2012) field experiments were conducted for comparing the soil and crop productivity under organic farming with that of inorganic and INF practices under RSB land configuration.

2.1. Site description

The field experiments were conducted at lowland Agronomy farm, ICAR Research Complex for North Eastern Hill (NEH) Region, Umiam, Meghalaya, India. The farm is located at 25°30′ N latitude and 91°51′ E longitude with an elevation of 950 m above mean sea level. No fertilizer and pesticides were used in the experimental site in previous two years prior to establishment of the current experiment. A monocropping of rice had been practiced with organic inputs such as farmyard manure (FYM), or, residue recycling. Soil samples were collected from the surface layer (0–15 cm) before initiation of the present study. The experimental soil had sandy loam texture, pH of 5.1, organic C 24.6 g kg^{-1}, available N 150.5 kg ha^{-1}, P 2.96 kg ha^{-1}and K 245.1 kg ha^{-1}. Soil of the experimental site is described a *Typic Paleudalf* (Bhattacharya et al., 1994).

2.2. Weather

The average monthly minimum and maximum temperature during the crop growing seasons ranged from 12.4 to 21.2 °C and from 23.9 to 29.1 °C, respectively (Suppl. Fig. S1). The long term (30 years) average annual rainfall of the study site is 2450 mm and the average annual rainfall of seven years study period was 2006 mm (Suppl. Fig. S1). The rainfall pattern and total rainfall received during the cropping seasons from 2005 to 12 are presented in Fig. 1. During the entire experimental period, the highest mean maximum temperature (Suppl. Fig. S2) was recorded in the month of April (26.83 to 29.4 °C) and August (27.49 to 29.73 °C). The mean lowest temperature (Suppl. Fig. S3) was recorded in the month of January (5.04 to 7.9 °C).

2.3. Layout

The experiment was conducted in a lowland paddy field. To accommodate vegetables in paddy field a RSB land configuration was adopted. The dimension of individual RSB was 7 m × 2 m × 0.3 m (Fig. 1). The RSB was developed in sequence to facilitate drainage and inter-plot water harvesting (Suppl. Figs. S4 & S5). The surface soil layer from sunken beds were removed and deposited on the adjacent area marked for raised bed to make a bed height of about 30 cm from the ground level. All the crop residues and weed biomass were placed below the raised beds and covered with the soil from sunken beds. Repairing was done every year to maintain the bed height without disturbing the layout. The organic block was isolated from inorganic and INF block in the field with a drainage channel of 0.5 m (Suppl. Figs. S4 & S5). To avoid any possible contamination (fertilizer, pesticide residues etc.) from inorganic block, the field slope gradient (2%) was maintained such that water drains out from organic via INF and inorganic blocks and not vice-versa.

2.4. Treatments

The experiment was laid out with treatment combinations of four rice-vegetable cropping sequences on raised beds, four rice (varieties)-fallow (no crop) sequences on sunken beds under four farming practices (isolated blocks). The four cropping sequences on raised beds comprised of rice – potato (*Solunum tuberosum* L.) (CS1), rice – tomato (*Solanum lycopersicum* L.) (CS_2), rice – French bean (*Phaseolus vulgaris* L.) (CS_3) and rice – carrot (*Daucus carota* L.) (CS_4). Four sequences on sunken beds were IR 64-fallow, Lampnah-fallow, Shahsarang-1-fallow and Krishna Hamsha-fallow, where IR 64, Lampnah, Shahsarang, and Krishna Hamsha were four rice varieties. Rice variety Bhalum 1 was used as test crop in raised beds. All the cropping sequences were maintained under four farming practices: (1) control-(only in-situ recycling of 2/3rd crop residues); (2) organic-100% recommended dose of N and P (RDNP) through organic manure and rock-phosphate, (3) inorganic-100% recommended dose of NPK through synthetic fertilizer (RDNPK), and (4) INF-50% RDNPK through inorganic fertilizers + 50% RDNP through organic manures. Thus, four cropping sequences each on raised beds and sunken beds were evaluated under four farming practices. All the treatments were replicated three times making the total number of raised and sunken beds as 48 each (4 × 4 × 3).

2.5. Crop culture

The details of crops cultivated, cultivars used, their duration, spacings, weed management and rate of application of nutrients are presented in Suppl. Table S1. Organic manures (FYM) were applied about a month before sowing/transplanting on the basis of N-equivalent under organic and INF farming as per the nutrient recommendation of the respective crops (Patel et al., 2015) during each season. To supply 100% P requirement under organic and 50% under INF, rock phosphate (RP) was used as supplement along with organic manure. Nutrient concentrations of FYM and RP are shown in Suppl. Table S2. About 30 cm standing rice stubbles were retained under organic and INF and 60 cm under control. The variable stubble heights were maintained to meet the treatment requirement. Under INF and organic, at least 30 cm stubbles (as ideal condition) were retained for nutrient cycling, rest was removed as straw for cattle. Under control, since no fertilizer was applied, a minimum condition of nutrient cycling was facilitated by leaving 2/3rd stubbles in the field. However, traditionally, farmers do not apply any fertilizer or manure and rely on inherent soil fertility, and thus, many lowland farmers leave up to 60 cm stubbles in the field. On the other hand, the residues were

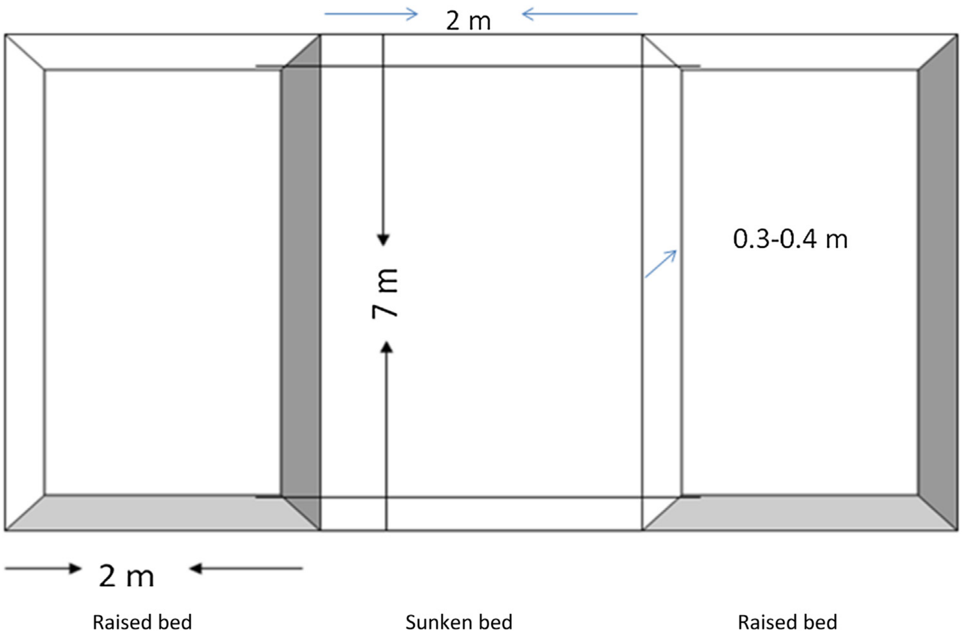

Fig. 1. A sketch of raised and sunken bed land configuration.

harvested by cutting from the ground (retaining only about 10 cm) under inorganic practice. The recommended doses of NPK under inorganic were provided through urea (46% N), single superphosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively.

Four high yielding rice varieties namely Shahsarang 1, IR 64, Krishna Hamsha and Vivek Dhan 82 were transplanted in the first week of July every year. The 25-day old rice seedlings were transplanted on sunken beds using a spacing of 20 × 15 cm and 2–3 seedlings per hill. Rice yield was recorded at 14% grain moisture content. The vegetables such as potato [cultivar (cv.) Kufri Jyoti], pole-type French bean (cv. Naga local), carrot (cv. New Kuroda) and tomato (cv. Rocky) were grown during the pre-rainy season (January to May) on raised beds. After harvest of vegetables, rice variety Bhalum 1 was cultivated on raised beds in all the sequences. Rice on raised bed was sown during 3rd week of June every year in line with a row to row spacing of 20 cm. Staking was provided to pole type French bean. French bean was harvested as green pods through multiple picking.

2.6. Pest and disease management

2.6.1. Organic farming

Neem (*Azadirachta indica*) cake was applied at 150 kg ha^{-1} during last ploughing every year and mixed with the soil to manage soil borne insect-pest and diseases. Neem oil 3 mL L^{-1}, Derisom 2.5 mL L^{-1} (a product of *Deris indica*) of water was applied at flowering stage and 15 days after that for control of insect pests and diseases as preventive measures. Diseased leaves were stripped off manually whenever possible. Weeds in sunken bed rice were managed by two hand weedings (HW) at 25 and 50 days after transplanting (DAT) and one weeding with rotary-weeder at 40 DAT. Whereas, in case of raised bed rice, two HW were given at 25 and 50 days after sowing (DAS). Weeds in raised bed vegetables were managed through HW, hoeing and earthing up. All the weed biomass was recycled into the soil irrespective of treatments.

2.6.2. Inorganic, INF and control

In case of inorganic and INF practices, pesticides such as Tricylazole (75% WP) 2 mL L^{-1}, monocrotophos (36% SL) 2 mL L^{-1} etc. were used to control insect pest and diseases. However, weed management under organic, INF and control has been done similar to those under organic management practices. No pesticides were used in case of control for insect and disease management.

2.7. Plant and soil sampling and analyses

Performance of crops were evaluated in terms of yield. Yield of different vegetable crops were converted to Rice Equivalent Yield (REY) for comparison. The REY of different crops under various farming practices was calculated on the basis of prevailing market prices. The REY was computed as following (De Wit, 1960):

$$\text{REY} = \{\text{Yield of vegetables (kg ha}^{-1}) \times \text{price of vegetables (\$ kg}^{-1})\} / \text{Price of rice (\$ kg}^{-1})$$

Fruit quality of tomato was determined at maximum ripening stage. Five randomly collected fruits of tomato from the first harvest were selected from each treatment and processed to determine various quality parameters such as juice volume, total soluble solids (using Erma Hand Refractometer, 0–32^0brix), acidity and ascorbic acid (AOAC, 1980), reducing sugar, total sugar and lycopene content (Rangana, 1997). Similarly, root quality parameters of carrot such as root diameter, specific gravity, total soluble solids, ascorbic acid, beta carotene (Srivastava and Kumar, 2002), total carotenoides (Rodriguez-Amaya and Kimura, 2004), reducing sugar and total sugar (Rangana, 1997) were determined.

Soil samples (one sample from each plot) were collected from 0 to 15 cm depth before initiation of the study (2005) and after seven cropping cycles (2012) and analyzed for various physico-chemical and biological properties. Intact core samples (5.8 cm diameter and 5.4 cm length) were obtained using a manually driven core sampler. The samples were oven dried at 105○C for 24 h, and bulk density (ρ_b) was calculated based on oven dry weight (Blake and Hartge, 1986). The soil-pH was determined in a 1:2.5 soil: water suspension (Jackson, 1973). Total C concentration was determined by the dry combustion method (Nelson and Sommers, 2005) using a TOC analyzer (Elementar Vario TOC Select, Germany). Concentration of SOC was assumed to be equal to the total C, because of the negligible inorganic C concentrations as soil pH was <6.5 (Jagadamma and Lal, 2010). Soil available P was determined by Bray method (Bray and Kurtz, 1945) and available K by ammonium acetate extraction methods (Jackson, 1973). The soil microbial biomass carbon (SMBC) was determined by the ethanol-free chloroform fumigation extraction method (Vance et al., 1987) using a constant (Kc) value of 0.45 (Jerkinson and Lad, 1981).

Nutrient uptake (N, P and K) was monitored for only two years (2006–07 and 2007–08) in the present study. At crop maturity, sub samples of rice and vegetables were collected from each plot and dried in a hot-air oven at 65 °C. Plant samples were ground to pass through a 0.5-mm sieve and analyzed for total N by micro-Kjeldahl method (Bremner and Mulvaney, 1982). P concentration of plant tissues (digested in HNO_3 and $HClO_4$) was determined by the ammonium molybdate method (Olsen and Sommers, 1982) and that of K by flame photometry (Baruah and Borthakur, 1998). Nutrient uptake (for the above ground biomass only) was estimated by multiplying the N, P and K concentration of economic parts and straw/stover with their respective yield in kg ha^{-1} and summing up the two values.

2.8. Statistical analyses

Data were statistically analyzed using the F-test and test of significance of the treatment differences was done on the basis of the *t*-test (Gomez and Gomez, 1984). All parameters except yield were analysed using Split Plot Design (SPD). Summarized analysis of variance (ANOVA) of a single parameter (for example available phosphorus) using SPD has been presented in Suppl. Table S3. The yield of individual crops were statistically analysed separately in a Randomized Block Design (RBD) to assess the impact of farming practices. Summarized ANOVA of a single parameter (for example tomato fruit yield) using RBD has been presented in Suppl. Table S4. However, to assess the system as a whole, the yield of component crops were converted to REY and then analysed in SPD. The significant differences between treatment means were compared with the least significant difference (LSD) at $p = 0.05$. The difference between two treatment means which were higher than the respective LSD values were considered as significant.

3. Results

3.1. Soil quality parameters

3.1.1. Physical properties

Soil ρ_b in raised beds after seven cropping cycles were not influenced by the cropping systems, whereas, farming practices had significant effect on ρ_b (Table 1). The ρ_b under inorganic was significantly higher by 9.82% and 7% than those observed under organic, and INF practices, respectively. However, the highest ρ_b was observed under control after seven cropping cycles. A similar trend in ρ_b was observed in case of sunken beds. The water holding capacity (WHC) under raised and sunken beds were significantly higher under organic than those recorded under inorganic and

Table 1
Soil properties as influenced by cropping systems and farming practices in raised beds after seven cropping cycles.

Treatments	Bulk density ($Mg\ m^{-3}$)	WHC (%)	pH	SOC ($g\ kg^{-1}$)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)	SMBC ($\mu g\ g^{-1}$ dry soil)
Cropping sequences								
Rice-potato	1.20a	51.2a	5.13a	27.5a	241.2ab	16.5a	264.4a	141.4c
Rice-tomato	1.19a	51.4a	5.14a	27.7a	237.6b	16.8a	263.7a	144.1b
Rice-French bean	1.18a	52.4a	5.10a	28.0a	246.3a	17.8a	267.6a	148.6a
Rice-carrot	1.21a	51.5a	5.11a	27.0a	240.9ab	16.5a	261.8a	143.8bc
SEm (±)	0.01	1.35	0.05	00.7	1.84	0.94	1.64	1.10
LSD ($p=0.05$)	NS	NS	NS	NS	6.37	NS	NS	3.21
Nutrient sources								
Control	1.28a	47.9b	4.97b	22.6c	213.6d	9.43c	236.8c	117.4d
Organic	1.12d	55.6a	5.24a	31.2a	258.1b	21.1a	273.2b	177.9a
Integrated	1.15c	55.3a	5.27a	30.0a	266.4a	22.1a	286.9a	147.0b
Inorganic	1.23b	47.7b	5.00b	26.3b	227.8c	14.9b	260.7b	135.6c
Initial	1.19	45.9	5.10	24.6	150.5	2.96	245.1	–
SEm (±)	0.01	0.83	0.05	00.7	1.69	0.69	1.49	1.17
LSD ($p=0.05$)	0.02	2.43	0.17	2.1	4.95	2.04	4.36	4.04

SEm – standard error of mean, LSD-least significant difference, SOC – soil organic carbon, SMBC – soil microbial biomass carbon, WHC – water holding capacity, Organic – 100% nutrient requirement (N and P equivalent basis) met through organic sources, Integrated – 50% nutrient supplied through organic and remaining 50% through inorganic, inorganic – 100% nutrient supplied through inorganic sources, Initial – before initiation of the present study, means with the same letter within a column are not significantly different at $p=0.05$.

control. However, there was no significant ($p=0.05$) difference between WHC under organic and INF. The WHC observed under organic farming in raised and sunken beds were 16.6% and 29.7% higher than those recorded under inorganic, respectively.

3.1.2. Chemical properties

In general, pH recorded after seven year was lower under raised beds than those under sunken beds. The cropping system did not influence soil pH significantly after seven cropping cycles, although, the farming practices had significant effect on soil pH. Soil pH was significantly higher under organic and INF than under inorganic and control (Tables 1 & 2).

After seven cropping cycles, the highest soil available N, P and K were observed under rice-French bean sequence on raised bed (Table 1). However, only soil available N under rice-French bean sequence was significantly higher by 3.7% than that under rice-tomato. On the other hand, soil P and K were not statistically different under all cropping sequences. Among farming practices, available N, P and K in soil was the highest under INF followed by organic, inorganic and control. On sunken beds, rice varieties did not influence soil available N and P but had significant effect on soil-K content. Variety Shahsarang 1 had the highest soil available K content followed by IR 64. Among farming practices, soil available N was the highest under INF followed by organic, both of which were significantly higher compared to inorganic and control. Soil available N content under INF and organic were higher by 4.77% and 4.36% than inorganic and 18.2% and 17.8% than control, respectively. Whereas, soil available P was significantly higher under inorganic than control but remained at par with organic and INF. Soil available P under inorganic, organic and INF were 89.4, 85.9 and 82.3% higher than those observed under control, respectively. Soil available K was significantly higher under organic than those under control and inorganic but remained at par with INF (Table 2). Available K content under organic was 13.8% and 4.4% higher than those observed under control and inorganic, respectively.

At the end of seven cropping cycles, SOC content was not significantly changed by cropping sequences under raised bed (Table 1). However, among the farming practices, organic ($31.2\ g\ kg^{-1}$) being at par with INF ($30.\ g\ kg^{-1}$) had significantly higher SOC concentration than inorganic ($26.3\ g\ kg^{-1}$) and control ($22.6\ g\ kg^{-1}$). Under sunken bed system, although rice-fallow

Table 2
Soil properties as influenced by cropping systems and farming in sunken beds after seven cropping cycle.

Treatments	Bulk density ($Mg\ m^{-3}$)	WHC (%)	pH	SOC ($g\ kg^{-1}$)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)	SMBC ($\mu g\ g^{-1}$ dry soil)
Cropping sequences								
IR 64-fallow	1.18a	53.2a	5.35a	25.2a	218.6a	12.3a	265.4abc	119.3a
Shahsarang 1–fallow	1.18a	52.4a	5.32a	26.0a	219.6a	14.5a	267.6a	119.7a
Vivek Dhan 82- fallow	1.18a	53.0a	5.32a	25.3a	219.5a	13.8a	262.5bc	123.1a
K. Hamsa- fallow	1.17a	52.9a	5.33a	25.5a	218.2a	14.2a	261.3c	120.5a
SEm (±)	0.01	0.86	0.02	00.3	0.64	0.58	1.25	2.27
LSD ($p=0.05$)	NS	NS	NS	NS	NS	NS	4.34	NS
Nutrient sources								
Control	1.24a	44.9c	5.17d	23.2d	195.1c	8.5b	243.6d	103.5d
Organic	1.13c	61.5a	5.36b	26.4b	229.8a	15.8a	277.2a	146.8a
Integrated	1.15c	59.8b	5.50a	27.5a	230.7a	15.5a	273.8b	105.3c
Inorganic	1.19b	47.4c	5.28c	24.8c	220.2b	16.1a	262.3c	127.1b
Initial	1.25	46.0	5.1	20.1	142.2	1.9	244.6	–
SEm (±)	0.01	0.87	0.02	00.2	1.11	0.41	1.26	0.96
LSD ($p=0.05$)	0.03	2.55	0.04	00.5	3.25	1.18	3.68	3.33

SEm – standard error of mean, LSD-least significant difference, SOC – soil organic carbon, SMBC – soil microbial biomass carbon, WHC – water holding capacity, Organic – 100% nutrient requirement (N and P equivalent basis) met through organic sources, Integrated – 50% nutrient supplied through organic and remaining 50% through inorganic, Inorganic – 100% nutrient supplied through inorganic sources, Initial – before initiation of the present study, means with the same letter within a column are not significantly different at $p=0.05$.

sequences did not significantly influence SOC content, INF had significantly higher SOC concentration (27.5 g kg^{-1}) than that under other farming practices (Table 2). However, the SOC concentrations under organic (26.4 g kg^{-1}) was significantly higher by 6.5% and 13.8% than those observed under inorganic (24.8 g kg^{-1}) and control (23.2 g kg^{-1}), respectively.

3.1.3. Biological properties

The SMBC was significantly higher under organic compared to INF, inorganic and control in both raised and sunken beds (Tables 1 and 2). However, SMBC concentrations under INF and inorganic were also significantly higher by 20.1% and 15.5% than control, respectively. Cropping systems had significant effect on SMBC in raised beds, whereas it was not significant in-case of sunken beds (Tables 1 and 2). Soils under rice-French bean sequence on raised beds had significantly higher SMBC (3.1–5.1%) than all other sequences.

3.2. Crop productivity

3.2.1. Crop productivity under raised beds

While organic, inorganic and INF farming practices had no significant differences in rice yield, however all three enhanced rice grain yield significantly (54–61%) than that recorded under control (2.18 Mg ha^{-1}) over the seven years of experimentation. Average rice productivity was the highest under organic (3.5 Mg ha^{-1}) and INF (3.5 Mg ha^{-1}) followed by inorganic (3.35 Mg ha^{-1}) management practice. Irrespective of farming practices, seven years average grain yield of rice was not significantly different under all cropping sequences (Tables 3 and 4).

Potato tuber yield (Table 3) was significantly higher under INF than that under other farming practices in the first year (2005–06). Inorganic and organic practices gave statistically similar yield in 2005–06. During other years, the highest tuber yield was obtained under INF followed by organic and inorganic treatments (Table 3). During 7th year, yield recorded under organic and INF were statistically similar. Average tuber yield of potato was significantly ($p = 0.05$) higher under INF by 17.1% and 260% than those under inorganic and control, respectively. Average tuber yield under INF and organic were 260% and 237% higher than that under control, respectively. The average tuber productivity under organic was ~10% higher than that recorded under inorganic.

Tomato yield was recorded the highest under organic and remained similar with INF in most of the years followed by inorganic treatments (Table 3). Average tomato yield under organic was 25.6% higher than inorganic and 82.9% higher than that under control.

French bean green pod yield (Table 4) was recorded significantly ($p = 0.05$) higher under inorganic than organic and control in 1st year (2005–06). However, the pod productivity under inorganic and INF was not statistically different. Whereas, from 2nd to 7th year, the highest green pod yield was recorded under INF followed by organic. Seven years average green pod yield was also significantly higher under INF by 10, 16 and 262% than organic, inorganic and control, respectively, however, the average pod productivity under organic and inorganic were significantly higher than control by 229.2% and 212.6%, respectively as well.

Carrot root yield was recorded the highest under INF over the experimental period. Average root yield was the highest under INF (10.4 Mg ha^{-1}) that was statistically similar to organic farming (10.1 Mg ha^{-1}) but both of these were significantly higher than inorganic and control (Table 4). The carrot root yield under INF and organic were 46.5% and 42.3% higher than that recorded under inorganic, respectively.

3.2.2. Cropping system productivity on raised beds

Total productivity of the cropping systems in terms of REY in raised bed was the highest under INF followed by organic in the 1st and 3rd year, whereas, in 2nd year the highest REY was recorded under organic followed by INF (Table 5). From 4th year onward, organic had greater REY compared to INF and inorganic. Average REY of seven years was the maximum under organic (18.1 Mg ha^{-1}) followed by INF (17.2 Mg ha^{-1}) and inorganic (16.6 Mg ha^{-1}). Average REY was 220, 202 and 175.5% higher under organic, INF and inorganic relative to control (5.9 Mg ha^{-1}), respectively. Among the cropping systems, rice – tomato gave the maximum REY in 1st, 2nd, 4th and 6th year of experimentations, whereas, in 3rd, 5th and 7th year, the highest REY was recorded with rice-carrot system. Average REY (seven year) was the highest with rice-tomato (17 Mg ha^{-1}) followed by rice-carrot (14.6 Mg ha^{-1}) and rice –potato (13.6 Mg ha^{-1}) sequences (Table 5).

Table 3

Productivity (Mg ha^{-1}) of rice-vegetable systems as impacted by farming practices on raised beds.

Nutrient sources/	Rainy season crop (Rice)								Pre-Rainy season (Tomato/Potato/Carrot/French bean)							
Year	I	II	III	IV	V	VI	VII	Avg.	I	II	III	IV	V	VI	VII	Avg.
CS$_1$: Rice-potato cropping sequence																
Control	2.8	2.7	2.4	2.2	2.0	1.5	1.5	2.1b	5.3	4.8	4.6	3.7	1.4	5.8	2.3	4.00d
Organic	3.6	3.8	3.8	3.4	3.4	2.9	3.1	3.4a	12.6	11.4	10.9	13.8	15.2	15.8	14.5	13.5b
Inorganic	3.6	3.7	3.7	3.3	3.3	3.0	3.2	3.4a	12.8	11.0	10.6	11.2	13.8	14.0	12.3	12.3c
Integrated	3.6	3.7	3.7	3.6	3.4	3.1	3.3	3.5a	13.5	12.4	12.1	15.7	16.3	16.3	14.7	14.4a
Average	3.4	3.5	3.4	3.1	3.0	2.6	2.8	3.1	11.1	9.9	9.6	11.1	11.7	13.0	11.0	11.1d
SEm (±)	0.14	0.12	0.11	0.09	0.16	0.12	0.19	0.11	0.17	0.20	0.15	0.12	0.06	0.17	0.37	0.14
LSD ($p = 0.05$)	0.42	0.35	0.33	0.27	0.49	0.35	0.58	0.32	0.50	0.57	0.45	0.37	0.20	0.57	1.29	0.43
CS$_2$: Rice-Tomato cropping sequence																
Control	2.7	2.7	2.4	2.2	2.1	1.5	1.8	2.2b	8.35	5.88	5.57	5.20	0.76	0.51	0.10	3.77c
Organic	3.8	3.9	3.9	3.5	3.5	3.0	3.1	3.5a	29.8	25.1	23.6	23.8	18.3	21.3	13.1	22.1a
Inorganic	3.5	3.6	3.6	3.2	3.4	2.9	3.3	3.4a	28.2	19.2	18.0	17.5	14.6	14.2	11.7	17.6b
Integrated	3.9	3.8	3.7	3.3	3.4	3.1	3.4	3.5a	28.4	24.0	23.6	23.9	18.5	21.6	13.5	21.9a
Average	3.5	3.5	3.4	3.0	3.1	2.6	2.9	3.1	23.7	18.5	17.7	17.6	13.0	14.4	9.6	16.3
SEm (±)	0.07	0.08	0.08	0.11	0.09	0.13	0.12	0.09	0.25	0.18	0.26	0.21	0.15	0.25	0.36	0.39
LSD ($p = 0.05$)	0.21	0.23	0.23	0.33	0.27	0.38	0.37	0.28	0.75	0.55	0.77	0.64	0.52	0.87	1.23	1.16

I–VII and Avg. are 2005–06, 2006–07, 2007–08, 2008–09, 2009–10, 2010–11, 2011–12 and average, respectively, SEm – standard error of mean, LSD – least significant difference, Average – adding replication of respective years and then analyzing the data, Organic – 100% nutrient requirement (N and P equivalent basis) met through organic sources, Integrated – 50% nutrient supplied through organic and remaining 50% through inorganic, Inorganic – 100% nutrient supplied through inorganic sources, means with the same letter within a column are not significantly different at $p = 0.05$.

Table 4
Productivity (Mg ha^{-1}) of rice-vegetable systems as impacted by farming practices on raised beds.

Nutrient sources/	Rainy season crop (Rice)								Pre- Rainy season (Tomato/Potato/Carrot/French bean)							
Year	I	II	III	IV	V	VI	VII	Avg	I	II	III	IV	V	VI	VII	Avg
CS$_3$: Rice – French bean cropping sequence																
Control	2.8	2.7	2.7	2.5	2.0	1.6	2.0	2.3b	4.0	3.3	3.4	2.5	2.1	1.3	0.4	2.4c
Organic	3.9	4.0	4.0	3.6	3.4	3.1	3.3	3.6a	8.2	6.0	6.9	7.2	9.1	8.7	9.4	7.9b
Inorganic	3.3	3.2	3.7	3.5	3.3	2.9	3.4	3.3a	9.0	5.9	5.9	6.9	9.4	7.5	7.8	7.5b
Integrated	3.7	3.8	3.8	3.5	3.4	3.1	3.5	3.5a	8.8	6.2	7.3	7.5	12.0	9.5	9.7	8.7a
Average	3.4	3.4	3.6	3.3	3.0	2.7	3.1	3.2	7.5	5.4	5.9	6.0	8.2	6.8	6.8	6.6
SEm (±)	0.11	0.13	0.11	0.10	0.08	0.14	0.12	0.09	0.17	0.17	0.25	0.14	0.01	0.18	0.30	0.17
LSD ($p = 0.05$)	0.32	0.33	0.33	0.29	0.23	0.43	0.37	0.28	0.52	0.50	0.74	0.43	0.04	0.63	1.03	0.50
CS$_4$: Rice-carrot cropping sequence																
Control	2.6	2.5	2.5	2.1	2.0	1.5	1.7	2.1b	3.9	3.8	3.6	4.5	3.6	1.2	1.0	3.1c
Organic	3.6	3.8	3.8	3.5	3.4	3.1	3.2	3.5a	7.8	6.6	6.2	14.0	11.9	11.9	12.0	10.1a
Inorganic	3.5	3.4	3.4	3.4	3.4	2.7	3.2	3.3a	7.8	6.0	5.9	8.1	7.9	7.2	6.9	7.1b
Integrated	3.9	3.7	3.7	3.5	3.4	3.0	3.3	3.5a	8.0	6.4	6.4	14.8	13.0	12.5	11.6	10.4a
Average	3.4	3.4	3.4	3.1	3.0	2.6	2.8	3.1	6.9	5.7	5.5	10.4	9.1	8.2	7.9	7.6
SEm (±)	0.12	0.14	0.12	0.10	0.17	0.14	0.19	0.11	0.14	0.12	0.17	0.22	0.09	0.12	0.18	0.13
LSD ($p = 0.05$)	0.37	0.43	0.36	0.31	0.50	0.42	0.58	0.32	0.42	0.35	0.50	0.65	0.30	0.43	0.65	0.40

I–VII and Avg. are 2005–06, 2006–07, 2007–08, 2008–09, 2009–10, 2010–11, 2011–12 and average, respectively, SEm – standard error of mean, LSD – least significant difference, Average – Adding replication of respective years and then analyzing the data, Organic –100% nutrient requirement (N and P equivalent basis) met through organic sources, Integrated – 50% nutrient supplied through organic and remaining 50% through inorganic, Inorganic – 100% nutrient supplied through inorganic sources, means with the same letter within a column are not significantly different at $p = 0.05$.

3.2.3. Rice productivity on sunken beds

In sunken bed, the highest rice yields were observed under INF followed by inorganic in the 1st, 2nd and 6th year of experimentation. In the 3rd, 4th, 5th and 7th year, the highest yields were found under INF followed by organic and inorganic. Thus, average yield was recorded maximum under INF followed by organic and inorganic. Seven year average data revealed that rice grain yields under INF, inorganic and organic were 69.0, 62.8 and 62.4% higher, respectively, than that under control. Rice variety Shahsarang 1 had the highest average productivity followed by IR 64 (Table 6).

Comparison of rice productivity on raised and sunken beds revealed that productivity in sunken beds were 14–66% higher than those in raised beds. While rice productivity on raised beds ranged from 2.1 to 3.5 Mg ha^{-1} (Tables 3 and 4), the productivity on sunken beds ranged from 3.5 to 4 Mg ha^{-1} (Table 5). However, considering REYs, the productivity on raised beds were 3.6–4.9 folds higher on raised beds than those in sunken beds.

3.3. Nutrient uptake

The maximum total (average of two years) uptake (removal) of N and P of raised bed crops were observed under organic (204.4 and 36.9 kg ha^{-1}, respectively), and statistically similar with INF (200.0 and 33.8 kg ha^{-1}, respectively) but remained significantly higher than those of inorganic and control (Figs. 2 and 3). Whereas, total K uptake was the highest under INF (233.2 kg ha^{-1}) followed by organic (225.9 kg ha^{-1}); both of these were significantly ($p = 0.05$) higher than inorganic and control. Among the cropping sequences, maximum total N, P and K uptake were obtained in rice-tomato (189.3, 31.9 and 290.3 kg ha^{-1}, respectively) followed by rice-potato (182.7, 28.6 and 262.9 kg ha^{-1}, respectively), both of which were at par with each other but remained significantly ($p = 0.05$) higher than remaining cropping sequences.

3.4. Produce quality

Tomato fruits under organic farming exhibited superior quality followed by INF in terms of most of the biochemical properties including total soluble solids (TSS), ascorbic acid, juice volume, total and reducing sugar and lycopene content (Table 7). The highest TSS, ascorbic acid, reducing sugar, total sugar and lycopene content were observed under organic, whereas, acidity and juice volume were higher under control and INF relative to inorganic and organic farming practices (Table 7).

Table 5
System productivity (Mg ha^{-1}) in terms of Rice Equivalent yield (REY) as impacted by cropping systems and farming practices on raised beds.

Year	I	II	III	IV	V	VI	VII	Avg.
Cropping sequences								
Rice-carrot	11.6d	10.5c	17.5a	15.5b	16.7a	14.8c	15.6a	14.6b
Rice-potato	12.9c	12.0b	10.4d	14.2c	14.7d	15.5b	13.7b	13.4c
Rice-French bean	13.5b	10.6c	12.0b	12.2d	15.4c	12.8d	14.2b	12.9c
Rice-tomato	23.2a	20.0a	11.0c	20.6a	16.0b	17.3a	11.3c	17.0a
SEm (±)	0.16	0.11	0.18	16.0	17.3	0.18	0.25	0.18
LSD ($p = 0.05$)	0.49	0.34	0.53	0.48	0.51	0.63	0.84	0.55
Nutrient sources								
Control	8.1b	7.4d	7.0c	6.8c	4.7b	4.1d	3.0c	5.9d
Organic	17.8a	15.9a	15.0a	20.3a	19.7a	20.0a	17.9a	18.1a
Inorganic	17.5a	13.5c	13.5b	15.7b	19.0a	17.9c	15.9b	16.6c
Integrated	17.8a	15.1b	15.2a	19.8a	19.4a	18.5b	18.1a	17.2b
SEm (±)	0.13	0.12	0.19	0.22	0.24	0.18	0.32	0.17
LSD ($p = 0.05$)	0.39	0.35	0.58	0.65	0.71	0.54	0.94	0.52

I–VII and Avg. are 2005–06, 2006–07, 2007–08, 2008–09, 2009–10, 2010–11, 2011–12 and average, respectively, SEm – standard error of mean, Average – adding replication of respective years and then analyzing the data (pooled), Organic – 100% nutrient requirement (N and P equivalent basis) met through organic sources,Integrated – 50% nutrient supplied through organic and remaining 50% through inorganic, Inorganic – 100% nutrient supplied through inorganic sources, means with the same letter within a column are not significantly different at $p = 0.05$.

Table 6
Rice productivity (Mg ha^{-1}) as influenced by various cropping systems and farming practices in sunken bed.

Year	I	II	III	IV	V	VI	VII	Avg.
Cropping sequences								
IR 64	4.1a	4.12ab	3.98a	3.14b	2.98b	3.0a	3.67a	3.57a
Shahsarang 1	3.78a	4.38a	4.27a	3.28a	3.20a	3.12a	3.80a	3.69a
Vivek Dhan-82	3.07b	3.42c	3.37b	3.00c	3.13ab	2.77b	3.12b	3.13b
Krishna Hamsa	3.64a	3.78bc	4.05a	3.1bc	3.14ab	3.16a	3.60a	3.50a
SEm (±)	0.14	0.13	0.12	0.04	0.05	0.08	0.14	0.09
LSD (p = 0.05)	0.43	0.40	0.37	0.12	0.16	0.26	0.42	0.28
Nutrient sources								
Control	2.75b	2.53b	2.46b	2.2b	2.10c	1.55b	2.03b	2.23b
Organic	3.82a	4.31a	4.43a	3.47a	3.49a	3.36a	4.04a	3.85a
Inorganic	3.95a	4.34a	4.28a	3.35a	3.34b	3.55a	3.89a	3.81a
Integrated	4.06a	4.52a	4.50a	3.50a	3.53a	3.61a	4.22a	3.99a
SEm (±)	0.17	0.18	0.19	0.05	0.04	0.18	0.13	0.13
LSD (p = 0.05)	0.50	0.55	0.56	0.16	0.12	0.52	0.46	0.40

I–VII and Avg. are 2005–06, 2006–07, 2007–08, 2008–09, 2009–10, 2010–11, 2011–12 and average, respectively. SEm – standard error of mean, Average – adding replication of respective years and then analyzing the data (average), Organic –100% nutrient requirement (N and P equivalent basis) met through organic sources, Integrated – 50% nutrient supplied through organic and remaining 50% through inorganic, Inorganic – 100% nutrient supplied through inorganic sources, means with the same letter within a column are not significantly different at p = 0.05.

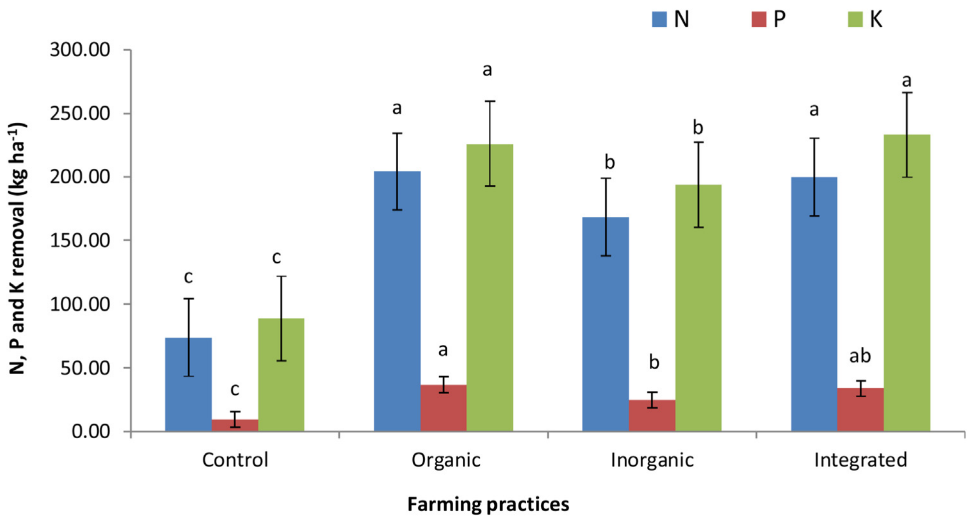

Fig. 2. Total (average of two years) removal of NPK as influenced by farming practices in raised beds (Capped vertical bars indicate standard errors; means with the same letter are not significantly different at p = 0.05).

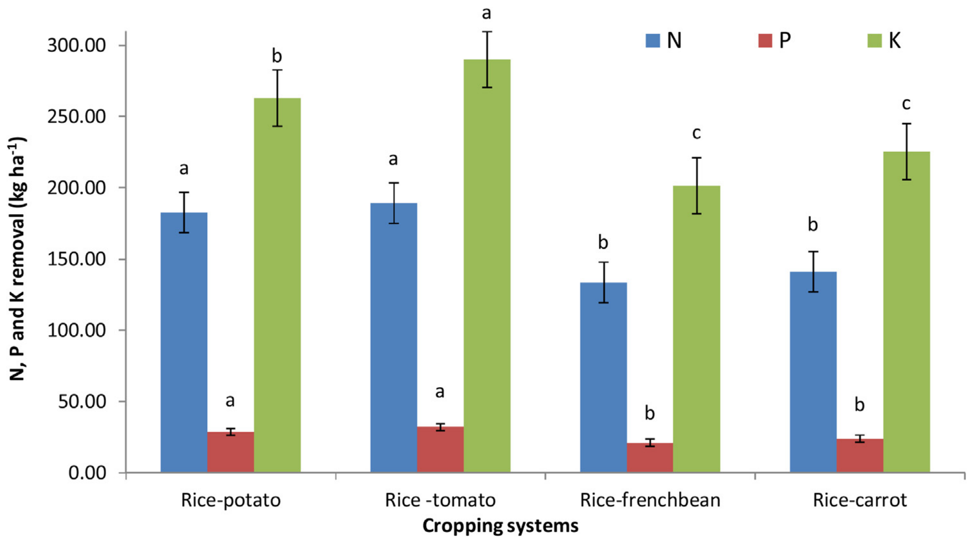

Fig. 3. Total (average of two years) removal of NPK as influenced by cropping system in raised beds (Capped vertical bars indicate standard errors; means with the same letter are not significantly different at p = 0.05).

Table 7
Quality parameters of tomato and carrot under different farming practices (Data as per 2011–12 analysis).

Quality parameters	Control	Organic	Inorganic	Integrated	Average
Tomato fruit					
Total soluble solid (%)	4.4 ± 0.12b	5 ± 0.13a	4.8 ± 0.14a	4.4 ± 0.11b	4.7 ± 0.13
Acidity (%)	0.77 ± 0.06a	0.64 ± 0.04b	0.67 ± 0.05b	0.64 ± 0.03b	0.7 ± 0.05
Ascorbic acid (mg 100 g^{-1})	28.6 ± 2.16b	31.5 ± 2.35a	31.3 ± 2.56a	28.6 ± 2.72b	30.0 ± 2.45
Juice volume (ml fruit^{-1})	64 ±3.0c	72 ± 4.58b	73 ± 4.58ab	77 ± 4.36a	71.5 ± 4.13
Reducing sugar (%)	1.5 ± 0.20c	2.3 ± 0.30a	1.6 ± 0.20bc	1.8 ± 0.30b	1.8 ± 0.25
Total sugar (%)	3.0 ± 0.20b	3.6 ± 0.20a	3.0 ± 0.10b	3.5 ± 0.26a	3.3 ± 0.19
Lycopene content (mg 100 g^{-1})	12.5 ± 0.60b	20.2 ± 0.89a	19.4 ± 0.56a	19.5 ± 0.46a	17.8 ± 0.63
Carrot root					
Root diameter (mm)	15.0 ± 0.62c	29.5 ± 0.91a	24.9 ± 0.85b	33.8 ± 0.92a	25.8 ± 0.83
Specific gravity (g ml^{-1})	1.08 ± 0.04c	1.39 ± 0.06ab	1.36 ± 0.04b	1.42 ± 0.06a	1.3 ± 0.05
Total soluble solid (%)	7.50 ± 0.36ab	8.27 ± 0.36a	6.55 ± 0.36c	7.30 ± 0.36b	7.4 ± 0.36
Ascorbic acid (mg 100 g^{-1})	34.00 ± 1.37b	40.13 ± 1.42a	35.50 ± 1.35b	38.45 ± 1.29a	37.0 ± 1.36
Acidity (%)	0.14 ± 0.02b	0.23 ± 0.03a	0.15 ± 0.02b	0.19 ± 0.02a	0.2 ± 0.02
Beta carotene (mg/100 g)	7.10 ± 0.30c	8.00 ± 0.40a	6.23 ± 0.42d	7.40 ± 0.36b	7.2 ± 0.37
Total carotenoids (mg g^{-1})	59.27 ± 0.87c	68.60 ± 0.82a	57.93 ± 0.71c	62.30 ± 0.89b	62.0 ± 0.82
Total sugar (%)	4.16 ± 0.24c	5.70 ± 0.30a	5.10 ± 0.26b	6.00 ± 0.26a	5.2 ± 0.27
Reducing sugar (%)	3.60 ± 0.10b	4.15 ± 0.18a	3.90 ± 0.10a	4.20 ± 0.17a	4.0 ± 0.14

±standard deviation, Organic – 100% nutrient requirement (N and P equivalent basis) met through organic sources, Integrated – 50% nutrient supplied through organic and remaining 50% through inorganic, Inorganic – 100% nutrient supplied through inorganic sources, means with the same letter within a raw are not significantly different at $p = 0.05$.

Quality parameters of carrot root (root diameter, specific gravity, TSS, ascorbic acid, acidity, beta carotene, total carotenoides, total sugar and reducing sugar) are presented in Table 7. The highest root diameter, specific gravity, total sugar and reducing sugar were observed under INF, whereas, TSS, ascorbic acid, acidity, beta carotene and total carotenoid were maximum under organic followed by INF.

4. Discussion

Organic and INF had significantly lower ρb and higher WHC than those recorded under inorganic and control after seven year of study (Tables 1 and 2). Other studies also indicated that organic farming has positive effects on several soil physico-chemical properties. Continuous application of organic manure such as FYM can help in improving physical properties of soil compared to application of chemical fertilizer alone (Bhatia and Shukla, 1982). Organic manures can counteract the deleterious effect on ρb that may be caused by the continuous use of mineral fertilizers and can increase the WHC (Vengadaramana and Jashothan, 2012). In the present study, soil pH was significantly higher under organic and INF than other farming practices (Tables 1 and 2). Organic manure probably had ameliorating effect on soil pH due to improvement in physical properties and reduction in Fe and Al toxicity as evident from another study (Das et al., 2014b).

In general soil available N, P and K were significantly ($p = 0.05$) higher under INF and organic than inorganic and control after seven year of experimentations (Tables 1 and 2). However, in sunken beds inorganic had the highest available P which was statistically similar to organic and INF. Long term application of organic amendments has been reported to improve the SOC, available P and K in soil (Panwar et al., 2010). Previous study indicated that about 25–30% of the N contained in compost and FYM can be absorbed by plants during one crop season and the accumulated nutrients from the continuous application of organic matter are gradually mineralized and utilized by successive crops sustaining the productivity (Inoko, 1984). In general, manures and composts are good sources of P with high plant availability as the majority of P present is inorganic and readily available to plants. Inorganic P accounts for 75–90% of the total P present in manure and compost (Eghball and Gilley, 2001). Studies have indicated that P uptake from manure and compost was equal to or greater than P uptake from commercial P fertilizers (Leytem and Westermann, 2005). In present study, rock-phosphate (RP) was used as supplementary P source along with organic manure for nutrition of crops under organic farming. Although the total P concentration can be relatively high (greater than 6.55%), the soluble P concentration in RP is very low (less than 1%). Thus, application of RP along with organic manure can lead to build up of soil P (Das et al., 2014b). Similar to the present results (Tables 1 and 2), the favorable effect of INF and organic farming on increasing the available N, P and K contents (Kumar et al., 2012) and buildup of SOC (Rudrappa et al., 2006) have been previously reported. The buildup of P, K, Ca, and Mg in top-soils under long-term manurial trials were also reported (Edmeades, 2003). This suitably explains the reason for higher available nutrient status under organic and INF than inorganic and control in the current study.

The SOC concentration under organic farming was significantly higher than inorganic and control but remained at par or lower than INF (Tables 1 and 2). A number of long-term experiments comparing conventional and organic practices have documented increase in OM/SOC under organically managed soils (Lotter, 2003). Addition of OM through manure and plant roots, and root exudates increase SOC. A further reason for SOC increase may be the slow decomposition of applied and native SOM due to prevailing high inherent SOC and difficultly in decomposing SOC under rice-ecosystem as had been reported by Singh et al. (2004). In addition to those reasons, in the current study, prevailing low temperatures also might have helped in building SOC by reduction of OM oxidation.

Among the cropping sequences, rice-French bean had significantly higher SMBC than other sequences (Table 1). The leguminous nature of French bean might have enhanced microbial activities due to symbiotic N-fixation, addition of N-rich leaf litter and biomass to soil. The SMBC was significantly ($p = 0.05$) higher under organic compared to INF, inorganic and control after seven cropping cycles (Tables 1 and 2). Continuous supply of sufficient OM under organic farming provides energy source for microbes and thus, enhances microbial activity in the soil (Patel et al., 2015). Soil microbes typically are C-limited (Smith and Paul, 1990), and lower microbial biomass in soils from conventional agroecosystems than that of soils under organic farm is often due to reduced organic C in soil (Fliebbach and Mader, 2000). The quantity and quality of organic inputs are the most important factors affecting microbial biomass and activity of microbes (Tu et al., 2006). The differences in microbial biomass and activity under different management practices may have implications for nutrient availability to crops. High microbial biomass and activity can lead to high nutrient availability to crops (Tu et al., 2006). Similar to the results obtained in our study (Tables 1 and 2), significant improvement in soil physical, chemical and biological properties under organic farming have been previously reported (Carpenter et al., 2000).

There was a mixed response of vegetables to farming practices in the present study. In general, the highest crop productivity for carrot, potato and French bean were obtained under INF, but, the tomato yielded maximum under organic (Tables 3 and 4). However, the responses of crops to INF and organic farming were statistically similar with each other and remained always higher than inorganic and control. Improvement in soil physico-chemical parameters such as pH, ρb, WHC, available N, P, K and biological parameters such as SMBC in present study (Tables 1 and 2) could be the reason for higher crop productivity under INF and organic farming practices than those of inorganic and control as evident from previous studies (Patel et al., 2015). Greater yields of carrot under organic than inorganic have been also reported by other researchers (Rembialkovska, 2003). Continuous application of organic manure promotes plant growth by supplying the necessary macro and micro-nutrients throughout the crop growth period and thus, sustain yields (Patel et al., 2015).

Relatively higher yield of tomato than other crops was responsible for achieving higher REY under rice-tomato sequence in current study (Table 5). Similar to the present study, the higher productivity and equivalent yield due to inclusion of tomato and carrot in rice based cropping system during pre-rainy season has been reported by other researchers (Saha and Ghosh, 2010; Patel et al., 2015).

Organic, inorganic and INF farming practices being at par with each other produced significantly ($p = 0.05$) higher grain yield of rice on sunken beds than under control (Table 6). Barik et al. (2006) also reported that INF through organic and chemical sources increased the rice yield more relative to other nutrient sources. Higher yield of crops with integrated application of recommended N, P, K and organic manure compared with other nutrient management practices has been reported by other researcher (Abedi et al., 2010). Although yield decline under organic farming especially during transition phase is widely documented, there are several reports of equal or higher yield under organic relative to conventional farming as well (Edmeades, 2003). It is argued that with adequate supply of nutrients, yields with organic sources tend to be similar to those with inorganic sources (Carl and Deborah, 2007). Better performance of crops under organic farming in certain agroecological conditions such as weak acidic to acidic soils, rainfed conditions than other conditions have also been reported (Seufert et al., 2012).

In present study, REY obtained from raised beds crops were substantially higher than those recorded for sunken beds, indicating the benefit of cultivating vegetables on raised bed after rice (Tables 5 and 6). Thus, higher equivalent yields on raised beds than those under sunken beds were due to inclusion of vegetables in sequence after rice. The high yield and return from vegetable component contributed to increasing REYs on raised beds (Das et al., 2010; Patel et al., 2015).

The total removal of N, P and K under organic and INF were statistically similar but significantly ($p = 0.05$) higher than control (Fig. 2). Higher nutrient uptake under organic and INF might be due to better soil health and less nutrient fixation leading to higher biomass production and nutrient removal by plants. Rice-potato and rice-tomato sequence removed significantly greater N, P and K than rice-carrot and rice-French bean sequences (Fig. 3). Higher nutrient uptake by potato under INF than conventional farming has been reported by previous researchers (Kumar et al., 2012). The increased N uptake was due to mineralization of N from continuous application of organic amendments and mineralization effect upon native N in a previous case (Sims, 1987). The increased P uptake under INF was earlier attributed to solubilization effect on the native P (Singh et al., 1981). The decomposition of organic manure results in the formation of CO_2, which helps in the solubilization of the native P and forms the phospho-humic complexes. Such complexes can be easily assimilated by the plants or isomorphous replacement of phosphate ions by humate ions, and coating of sesquioxide particles by humus to form a protective cover that reduces the P-fixing capacity of the soil (Das et al., 2004), making P readily available to plants for uptake.

The most of the studied quality parameters of tomato fruit and carrot root were better under organic and INF than inorganic and control (Table 7). Tomato fruits under organic farming exhibited superior quality followed by INF in terms of most of the biochemical properties including total soluble solids (TSS), ascorbic acid, juice volume, total and reducing sugar and lycopene content. Lower acidity content of fruits at ripening stage under organic management practices indicates superior quality (Anthon et al., 2011). The produce quality is controlled by a complex interaction of factors, including soil type and the ratios of minerals in added manures (Warman and Harvard, 1998). Enhancement in phenol, chlorophyll, ascorbic acid, oxalic acid, acidity, lycopene and carotenoid contents due to application of organic manure have been reported (Parray et al., 2007), and management of organic manures and crop rotation can have significant effect on yields and crop quality (Ramesh et al., 2008). There has been much speculation on the benefits of consuming crops grown on soils amended with organic materials as the primary source of plant nutrients compared with those grown conventionally with chemical fertilizers. For example, researchers have shown conflicting results with respect to the ascorbic acid (vitamin C) content of crops. Higher levels of ascorbic acid under application of organic manure relative to chemical fertilizers in *Brasica rapa* (Harwood, 1984) and in *Spinacia oleracea* (Ahrens et al., 1983) have also been reported. Most of the conflicting results that have been reported on crop response to chemical and organic fertilizers are most likely due to the fact that the organic materials mineralize at different rates, thus, providing different levels of inorganic N to the crop (Hornick and Parr James, 1987).

5. Conclusions

The results of seven-year experimentation revealed that the productivity of crops as well as of the system under INF was much better than inorganic but remained statistically similar to organic farming. Soil quality parameters such as available nutrients, SOC, WHC, ρ_b were statistically similar under organic and INF as well, whereas, SMBC was higher under organic than other farming practices. In general, soil quality parameters were the poorest under control followed by inorganic. Most of the produce quality parameters of tomato and carrot were better under organic relative to inorganic farming. Thus, the study indicated the opportunity of organic farming in the agro-climatic condition of studied ecosystem and supported the hypothesis that continuous organic farming promotes soil quality and sustains crop productivity.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.agee.2016.09.007.

References

AOAC, 1980. Official Methods of Analysis. Association of Official Analytical Chemists, Washington DC, USA.

Abedi, T., Alemzadeh, A., Kazemeini, S.A., 2010. Effect of organic and inorganic fertilizers on grain yield and protein banding pattern of wheat. Aust. J. Crop Sci. 4, 384–389.

Ahrens, E., Elsaidy, S., Samaras, I., Samaras, F., Wistinghausen, E., 1983. Significance of fertilization for the post-harvest condition of vegetables, especially spinach. Environmentally Sound Agriculture, William Lockeretz. Praeger, New York, pp. 239–246.

Anthon, G.E., LeStrange, M., Barrett, D.M., 2011. Changes in pH, acids, sugars and other quality parameters during extended vine holding of ripe processing tomatoes. J. Sci. Food Agric. doi:http://dx.doi.org/10.1002/jsfa.4312.

Baishya, K., 2015. Impact of agricultural chemicals application on soil quality degradation a review. Int. J. Sci. Technol. Manage. 4 (1), 220–228.

Baranski, M., Srednicka-Tober, D., Volakakis, N., Seal, C., Sanderson, R., Stewart, G.B., Benbrook, C., Biavati, B., Markellou, E., Giotis, C., Gromadzka-Ostrowska, J., Rembiałkowska, E., Skwarło-Sonta, K., Tahvonen, R., Janovska, D., Niggli, U., Nicot, P., Leifert, C., 2014. Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systematic literature review and meta-analyses. Br. J. Nutr. doi:http://dx.doi.org/10.1017/s0007114514001366.

Barik, A.K., Das, A., Giri, A.K., Chattopadhyay, G.N., 2006. Effect of organic (vermicompost, farmyard manure) and chemical sources of plant nutrients on productivity and soil fertility of kharif rice (*Oryza sativa* L.)]. Crop Res. 31 (3), 338–342.

Baruah, T.C., Borthakur, H.P., 1998. A Text Book of Soil Analysis. Vikas Publishing House Pvt. Ltd., New Delhi, pp. 297–301.

Bhatia, K.S., Shukla, K.K., 1982. Effect of continuous application of fertilizers and manure on some physical properties of eroded alluvial soil. J. Indian Soc. Soil Sci. 30 (1), 33–36.

Bhattacharya, T., Sen, T.K., Singh, R.S., Nayak, D.C., Sehgal, J.L., 1994. Morphology and classification of Ultisols with kandic horizon in North Eastern Region. J. Indian Soc. Soil Sci. 42, 301–306.

Bhattacharya, R., Kundu, S., Prakash, V., Gupta, H.S., 2008. Sustainability under combined application of mineral and organic fertilizers in a rainfed soybean-wheat system of the Indian Himalayas. Eur. J. Agron 28, 33–46.

Blake, G.R., Hartge, K.H., 1986. Bulk density. In: Klute, A. (Ed.), Methods of Soil Analysis, Part I. ASA Monograph No .9, pp. 363–376 (Madison).

Bray, R.H., Kurtz, L.T., 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Sci. 59, 39–45.

Bremner, J.M., Mulvaney, C.S., 1982. Nitrogen-total, In: Page, A.L., Miller, R.H., Keeney, D.R. (Eds.), Methods of Soil Analysis. Part 2. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI, pp. 595–624.

Bujarbaruah, K.M., 2004. Organic farming: opportunities and challenges in North Eastern region of India. Paper Presented in International Conference on *Organic Food*, ICAR Research Complex for NEH Region, Umiam, Meghalaya during 14–17 February, pp. 13–23.

Carl, J.R., Deborah, L.A., 2007. Exploring the benefits of organic nutrient sources for crop production and soil quality. Hortic. Technol. 17 (4), 422–430.

Carpenter, B.L., Kennedy, A.C., Reganold, J.P., 2000. Organic and biodynamic management effects on soil biology. Soil Sci. Soc. Am. J. 64, 1651–1659.

Cassman, K.G., Pingali, P.L., 1995. Extrapolating trends from long-term experiments to farmers' fields: the case of irrigated rice systems in Asia. Agricultural Sustainability: Economic Environmental and Statistical Considerations. John Wiley and Sons, New York, USA.

Das, A., Prasad, M., Shivay, Y.S., Subha, K.M., 2004. Productivity and sustainability of cotton (*Gossypium hirsutum* L.)–Wheat (*Triticum aestivum* L.) cropping system as influenced by prilled urea, farmyard manure and azotobacter. J. Agron. Crop Sci. 190, 298–304.

Das, A., Patel, D.P., Munda, G.C., Ghosh, P.K., Saha, R., Bordiloi, J., Kumar, M., 2010. Productivity and soil nutrient balance sheet as influences by in-situ biomass recycling in rice – vegetable cropping sequences. Environ. Ecol. 28 (1), 160–163.

Das, A., Patel, D.P., Ramkrushna, G.I., Munda, G.C., Ngachan, S.V., Kumar, M., Buragohain, J., Naropongl, a., 2014a. Crop diversification, crop and energy productivity under raised and sunken beds: results from a seven –year study in a high rainfall organic production system. Biol. Agric. Hortic. 30 (2), 73–87. doi: http://dx.doi.org/10.1080/01448765.2013.854709.

Das, A., Patel, D.P., Kumar, M., Ramkrushna, G.I., Ngachan, S.V., Layek, J., Lyngdoh, M., 2014b. Influence of cropping systems and organic amendments on productivity and soil health at mid altitude of North East India. Indian J. Agric. Sci. 84 (12), 1525–1530.

De Wit, C.T., 1960. On competition.Verslag land bouwkundige onderzoekingen. Wageningen 66, 1–81.

Edmeades, D.C., 2003. The long-term effects of manures and fertilisers on soil productivity and quality: A review. Nutr. Cycling Agroecosyst. 66, 165–180.

Eghball, B., Gilley, J.E., 2001. Phosphorus risk assessment index evaluation using runoff measurements. J. Soil Water Conserv. 56, 202–206.

Fliebbach, A., Mader, P., 2000. Microbial biomass and size-density fractions differ between soils of organic and conventional agricultural systems. Soil Biol. Biochem. 32, 757–768.

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M., Mueller, N.D., O'Connell, C., Ray, D.K., West, P.C., Balzer, C., Bennett, E.M., Carpenter, S.R., Hill, J., Monfreda, C., Polasky, S., Rockström, J., Sheehan, J., Siebert, S., Tilman, D., Zaks, D.P.M., 2011. Solutions for a cultivated planet. Nature 478, 337–342.

Franke-Snyder, M., Douds, D.D., Galvez, L., Phillips, J.G., Wagoner, P., Drinkwater, L., Morton, J.B., 2001. Diversity of communities of arbuscular mycorrhizal (AM) fungi present in conventional versus low-input agricultural sites in eastern Pennsylvania, USA. Appl. Soil Ecol. 16, 35–48.

Giles, J., 2004. Is organic food better for us? Nature (London) 428, 796–797.

Gomez, K.A., Gomez, A.A., 1984. Statistical procedure for agricultural research, International Rice Research Institute. 2nd ed. John Wiley and Sons, NY, USA.

Gopinath, K.A., Saha, R., Mina, B.L., Pande, H., Kundu, S., Gupta, H.S., 2008. Influence of organic amendments on growth, yield and quality of wheat and on soil properties during transition to organic production. Nutr. Cycl. Agroecosyst. 82, 51–60.

Harwood, R.R., et al., 1984. Organic farming research at the rodale research center. In: Bezdicek, D.F. (Ed.), Organic Farming: Current Technology and Its Role in a Sustainable Agriculture. ASA, CSSA, and SSSA, Madison, Wisconsin, pp. 1–17.

Hornick, S.B., Parr James, F., 1987. Restoring the productivity of marginal soils with organic amendments. Am. J. Altern. Agric. 2 (2), 64–68.

IFOAM, 1998. International Federation of Organic Agriculture Movements. IFOAM Basic Standards for Organic Production and Processing. IFOAM Publications, Tholey-Theley, Germany.

Inoko, A., 1984. Organic Matter and Rice. IRRI, Los Banos, Philippines, pp. 137–145.

Jackson, M.L., 1973. Soil Chemical Analysis. Prentice Hall of India, New Delhi.

Jagadamma, S., Lal, R., 2010. Distribution of organic carbon in physical fractions of soils as affected by agricultural management. Biol. Fertil. Soils 46, 543–554.

Jerkinson, D.S., Lad, J.N., 1981. Microbial biomass in soil: measurement and turnover. In: Paul, E.A., Ladd, J.N. (Eds.), Soil Biochemistry. Dekkar, New York, pp. 451–471.

Kumar, M., Baishya, L.K., Ghosh, D.C., Gupta, V.K., Dubey, S.K., Das, A., Patel, D.P., 2012. Productivity and soil health of potato (*Solanumtuberosum* L.) fields as influenced by organic manures, inorganic fertilizers and biofertilizers under high altitudes of Eastern Himalayas. J. Agric. Sci. 4 (5), 223–234. doi:http://dx.doi.org/10.5539/jas.v4n5p223.

Lawlor, K., Knight, B.P., Barbosa-Jefferson, V.L., Lane, P.W., Lilley, A.K., Paton, G.I., McGrath, S.P., O'Flaherty, S.M., Hirsch, P.R., 2000. Comparison of methods to investigate microbial populations in soils under different agricultural management. FEMS Microb. Ecol. 33, 129–137.

Leytem, A.B., Westermann, D.T., 2005. Phosphorus availability to barley from manures and fertilizers on a calcareous soil. Soil Sci. 170, 401–412.

Lotter, D.W., 2003. Organic agriculture. J. Sustainable Agric. 21, 59–128.

Martini, E.A., Buyer, J.S., Bryant, D.C., Hartz, T.K., Denison, R.F., 2004. Yield increases during the organic transition: improving soil quality or increasing experience? Field Crops Res. 86, 255–266.

Mishra, V.K., Saha, R., 2007. Effect of raised-sunken bed system on inter-plot water harvesting and productivity of rice *(Oryza sativa*) and French bean *(Phaseolous vulgaris*) in Meghalaya. Indian J. Agric Sci. 77 (2), 73–78.

Munda, G.C., Das, Anup, Patel, D.P., 2010. Evaluation of transplanted and ratooncrop for double cropping of rice (*Oryza sativa* L.) under organic input management in mid altitude sub-tropical Meghalaya. Curr. Sci. 96 (12), 1620–1627.

Nelson, D.W., Sommers, L.E., 2005. Total carbon, organic carbon and Organic Matter. In: spark, D.L. (Ed.), Analysis of Soil and Plants Chemical Methods. SSA Book Series: 5 Soil Sci. Soc. Am.. Am. Soc. Agron. Inc., Wisconsin, USA.

Olsen, S.R., Sommers, L.E., 1982. Phosphorus. In: Page, A.L., Miller, R.H., Keeney, D.R. (Eds.), Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties, Agronomy Monograph 9. ASA and SSSA, Madison, Wisconsin, USA.

Pan, G., Zhou, P., Li, Z., Pete, S., Li, L., Qiu, D., Zhang, X., Xu, X., Shen, S., Chen, X., 2009. Combined inorganic/organic fertilization enhances N efficiency and increases rice productivity through organic carbon accumulation in a rice paddy from the Tai Lake Region China. Agric. Ecosyst. Environ. 131, 274–280.

Panwar, N.R., Ramesh, P., Singh, A.B., Ramana, S., 2010. Influences of organic, chemical and integrated management practices on soil organic carbon and soil nutrient status under semi-arid tropical conditions in central India. Commun. Soil Sci. Plant Anal. 41, 1073–1083.

Parray, B.A., Ganai, A.M., Fazili, K.M., 2007. Physicochemical parameters and growth yield of tomato (*Lycopersicumesculentum*): role of farm yard manure and neem cake. Am.-Eur. J. Agric. Environ. Sci. 2 (3), 303–307.

Patel, D.P., Das Anup Kumar, M., Munda, G.C., Ngachan, S.V., Ramkrushna, G.I., Layek, J., Naropongla Buragohain, J., Somireddy, U., 2015. Continuous application of organic amendments enhance soil health, produce quality and system productivity of vegetable based cropping systems at subtropical eastern Himalayas. Exp. Agric. 51 (1), 85–106.

Pulleman, M., Jongmans, A., Marinissen, J., Bouma, J., 2003. Effects of organic versus conventional arable farming on soil structure and organic matter dynamics in a marine loam in the Netherlands. Soil Use Manage. 19, 157–165.

Ramesh, P., Panwar, N.R., Singh, A.B., Ramana, S., 2008. Effects of organic manures on productivity, soil fertility and economics of soybean (*Glycine max*) –durum wheat (*Triticum durum*) cropping system under organic farming in *vertisols*. Indian J. Agric. Sci. 78 (12), 1033–1037.

Rangana, S., 1997. Hand Book of Analysis and Quality Control of Fruit and Vegetable Products, 2nd edition Tata McGraw Hill Publ. Co., Ltd., New Delhi, pp. 88–89.

Rembialkovska, E., 2003. Organic farming as a system to provide better vegetable quality. Acta Hortic. 604, 473–479.

Rodriguez-Amaya, D.B., Kimura, M., 2004. HarvestPlus Handbook for Carotenoids Analysis HarvestPlus Technical Monograph 2. IFPRI and CIAT, Washington, DC and Cali, pp. 34–36.

Rudrappa, L., Purakayestha, T.J., Singh, D., Bhadraray, S., 2006. Long-term manuring and fertilization effects on soil organic carbon pools in a Typic Haplustept of semi-arid sub-tropical India. Soil Tillage Res. 88, 180–192.

Saha, R., Ghosh, P.K., 2010. Effect of land configuration on water economy, crop yield and profitability under rice (*Oryza sativa*)—based cropping systems in north-east India. Indian J. Agric. Sci. 80 (1), 16–20.

Sanwal, S.K., Yadav, R.K., Singh, P.K., 2007. Effect of types of organic manure on growth, yield and quality parameters of ginger (*Zingiber officinale*. Indian J. Agric. Sci. 77, 67–72.

Seufert, V., Ramankutty, N., Foley, J.A., 2012. Comparing the yields of organic and conventional agriculture. Nature 485, 229–232.

Sims, J.T., 1987. Agronomic evaluation of poultry manure as a nitrogen source for conventional and no tillage corn. Agron. J. 79, 563–570.

Singh, B.P., Chahal, R.S., Singh, M., 1981. Fertilizer management through organic and inorganic fertilizers in *bajra*-wheat crop sequence. Fertil. News 26, 16–19.

Singh, Y., Singh, B., Ladha, J.K., Khind, C.S., Khera, T.S., Beauno, C.S., 2004. Effects of residue decomposition on productivity and soil fertility in rice-wheat rotation. Soil Sci. Soc. Am. J. 68, 854–864.

Smith, J.L., Paul, E.A., 1990. The significance of soil microbial biomass estimations. In: Bollag, J.M., Stotzky, G. (Eds.), Soil Biochemistry, vol. 6. Marcel Dekker, Inc., New York, NY, pp. 357–396.

Srivastava, R.P., Kumar, S., 2002. Fruits and Vegetables Preservation-Principles and Practices. International Book Distributing Co., New York, pp. 353–363.

Tu, C., Ristaino, J.B., Hu, S., 2006. Soil microbial biomass and activity in organic tomato farming systems: effects of organic inputs and straw mulching. Soil Biol. Biochem. 38, 247–255.

Van Diepeningen, A.D., De Vos, O.J., Korthals, G.W., Van Bruggen, A.H.C., 2006. Effects of organic versus conventional management on chemical and biological parameters in agricultural soils. Appl. Soil Ecol. 31, 120–135.

Vance, E.D., Brookes, P.C., Jenkinson, D.S., 1987. Microbial biomass measurements in forest soils: the use of the chloroform fumigation incubation method in strongly arid soils. Soil Biol. Biochem. 19, 697–702.

Vengadaramana, A., Jashothan, P.T.J., 2012. Effect of organic fertilizers on the water holding capacity of soil in different terrains of Jaffna peninsula in Sri Lanka. J. Nat. Prod. Plant Resour. 2 (4), 500–503.

Warman, P.R., Harvard, K.A., 1998. Yield, vitamin and mineral contents of organically and conventionally grown potatoes and sweet corn. Agric. Ecosyst. Environ. 68, 207–216.

Williams, P.R., Hammitt, J.K., 2001. Perceived risks of conventional and organic produce Pesticides, pathogens and natural toxins. Risk Anal. 21, 319–330.

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