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Influence of cropping systems and organic amendments on productivity and soil health at mid altitude of North East India

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ABSTRACT

Field experiments were conducted during 2006-07 to 2008-09 to assess the response of different cropping systems and organic amendments on productivity and soil health at mid altitude (950 m MSL) of Meghalaya. The treatments consisted of two rice based (rice (*Oryza sativa* L.) + soybean [*Glycine max* (L.) Merr.] - rapeseed, rice + soybean - tomato (*Solanum lycopersicum* L.) and two maize based (maize (*Zea mays* L.) + soybean - groundnut (*Arachis hypogaea* L.), maize + soybean- French bean (*Phaseolus vulgaris* L.)) cropping systems and five organic amendments, viz. farmyard manure (FYM), vermicompost (VC), local compost (LC), combined sources of nutrient (1/3 FYM +1/ 3 VC + 1/3 LC) and control (no manure) as sources of nutrient supply. Organic manures were applied on N-equivalent basis and phosphorus requirement was compensated through rock phosphate. The results revealed that the yield of different crops were maximum under combined sources of nutrient supply (CSN). Pooled (3 years) maize equivalent yield (MEY) was the highest under FYM followed by CSN and remained at par with each other. The pooled MEY under FYM and CSN were 171 % and 162 % higher than control, respectively. Among the cropping systems, maize + soybean - French bean recorded the highest MEY (28.78 t/ha). Total N, P and K uptake was maximum with CSN and remained similar with FYM. Maximum bulk density, soil organic carbon, soil microbial biomass carbon, dehydrogenase enzyme activity, available N and K in soil after three cropping cycles were also recorded under CSN. Maize + soybean - French bean cropping system along with FYM as source of nutrient supply was found to be cost effective with optimum productivity during transition to organic farming.

Key words: Crops, Cropping systems, Organic crop production, Organic amendments, Soil properties

Food crops and vegetables grown using organic inputs are preferred over conventionally produced crops by the health conscious end users (Yiridoe *et al*. 2005). By March, 2011 India has brought more than 4.43 million hectare area under organic certification process (Yadav 2012). The world market for organic products was estimated at about $ 63 billion in 2013 and has risen by about 19 % per year during 2002 to 2011 (IFOAM 2013). Such expansion of organic market provides opportunity to the farmers to reap the benefits of trade with relatively high price premium (Gopinath *et al.* 2008). In view of growing demand for organic food products worldwide including India, the Northeastern Region of India has vast opportunity to emerge as major suppliers of organic products. As productivity of traditional systems in hills is often very low, organic agriculture can provide a solution to the food needs of poor farmers while relying on natural resources (Das *et al.* 2013). Application of organic manures improves soil physico-chemical properties and sustains the soil quality. Soil quality comprises soil fertility including biological activity which are closely related because it is through the biomass that the mineralization of the important organic elements occurs (Efthimiadou *et al.* 2010). Higher levels of total organic carbon, nitrogen, soluble phosphorus, microbial activity and soil microbial biomass carbon (SMBC) were reported from organic compared to that under inorganic soils. Organic manure influences soil productivity through their effect on soil physical, chemical and biological properties (Ramesh *et al*. 2009). Farmers of North Eastern Hill (NEH) region of India rarely apply any fertilizer or manure to field crops. About eight lakhs hectare area in north - east India can be classified as "organic by default". The use of agrochemicals like fertilizers (12 kg/ha) and pesticides is negligible. The region is therefore, identified as one of the potential zone for organic food production in India (Das *et al.* 2013). Keeping this in view, field experiments were conducted to evaluate effect of different organic inputs on productivity

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and soil health of rice and maize based cropping systems during transition to organic farming at mid altitude of Meghalaya.

MATERIALS AND METHODS

Field experiments were conducted at well drained field in organic block of ICAR Research Complex for NEH Region, Umiam Meghalaya (21.5°N - 29.5°N latitude, 85.5°E -97.3°E longitude and 950 m MSL). The soil of the experimental field was high in organic carbon (1.32 %), low in pH (4.5), available N (195.61 kg/ha), P (10.36 kg/ha) and high in K (212.10 kg/ha). The experiment was laid out in a split plot design with four cropping sequences in main plots, viz. CS1: rice (*Oryza sativa* L.) + soybean [*Glycine max* (L.) Merr.] (4:2 row ratio) – rapeseed, CS2: rice + soybean (4:2) - tomato (*Solanum lycopersicum* L.), CS3: maize (*Zea mays* L.) + soybean (2:2) – groundnut (*Arachis hypogaea* L.) and CS4: maize + soybean (2:2) – French bean (*Phaseolus vulgaris* L.) and five organic amendments in sub plots, viz. farmyard manure (FYM), vermicompost (VC), local compost (LC), combined sources of nutrient supply (1/3 FYM +1/3 VC + 1/3 LC) and compared with control (no manure). A uniform dose of lime @ 2 tonnes/ha was applied to ameliorate soil acidity in alternate years. Organic manures were applied on the basis of N-equivalent and phosphorus requirement was compensated through rock phosphate. The recommended dose for rice (60:60 kg N:P_2O_5), maize (60:60 kg N:P_2O_5), French bean (50:60 kg N:P_2O_5/ha), rapeseed (50:60 kg N:P_2O_5/ha), tomato (80:60kg N:P_2O_5/ha), soybean (20:60 kg N:P_2O_5/ha) and groundnut (20:60 kg N:P_2O_5/ha) were applied with organic manures as per treatments on the basis of nutrient concentration in respective manure. The N, P and K contents in FYM were 0.84 ± 0.09, 0.56 ± 0.03 and 1.02 ± 0.06 %; in VC were 1.49 ± 0.10, 0.59 ± 0.07 and 1.05 ± 0.07 % and in that of LC were 0.58 ± 0.05, 0.28 ± 0.03, and 0.52 ± 0.03%, respectively. Thus, to supply 80 kg N about 9.5 tonnes FYM was applied that would supply about 53 kg P. The remaining 7 kg P was compensated through rock phosphate. High yielding varieties of rice (Bhalum-1), maize (DA 61-A), French bean (Naga local), tomato (Avinash-2) and rapeseed (M-27) were used as test crop. The *kharif* (rainy season) crops were raised as rainfed, whereas, for pre-*kharif* crops (January to May), life saving irrigation was given. Irrigations were adjusted as per the rainfall received during the season. In tomato, frequent life saving irrigations (weekly intervals) was given for better seedling establishment after transplanting. Staking was given in French bean for providing support using bamboo sticks.

Yield of different crops were converted to MEY for comparison of treatments. The MEY of different crops were calculated on the basis of prevailing market prices. The post harvest soil samples were collected from 0 to 15 cm depth for analyzing the available nutrient status, dehydrogenase activity (DHA) and microbial biomass carbon (MBC) at the end of three cropping cycles. The nutrient content in different crops were determined at harvest following standard procedures to calculate nutrient uptake. Insect pest and diseases were controlled through organic means. Organic block was protected from all possible contaminations by giving proper drainage, buffer zone, bunds etc.

The analysis of variance method was followed to statistically analyze the various data. The significance of different sources of variations was tested by error mean square of Fisher Snedecor's 'F' test at probability level (P = 0.05).

RESULTS AND DISCUSSION

Crop productivity

Rice grain yield was maximum with FYM followed by combined sources of nutrient supply (CSN) in the year 2006-07 (Table 1). However, from second year (2007-08) onwards, maximum grain yield was recorded under CSN.

Table 1 Crop productivity (tonnes/ha) as influenced by rice based cropping systems and nutrient sources

Nutrient source	*Kharif* crop (Rice)			Intercrop (Soybean)			*Rabi*/pre-*kharif* (Rapeseed/tomato)		
	2006-07	2007-08	2008-09	2006-07	2007-08	2008-09	2006-07	2007-08	2008-09
Rice + soybean – rapeseed (CS 1)									
FYM	2.32	2.22	2.05	1.21	1.32	1.16	1.07	1.27	1.21
Vermicompost	2.00	1.87	1.80	1.0	1.14	1.04	1.20	1.25	1.19
Local compost	1.37	1.80	1.59	0.75	1.13	1.03	0.73	0.98	1.06
Combined source	2.3	2.61	2.33	1.19	1.41	1.34	1.17	1.33	1.35
Control	0.82	1.20	1.04	0.53	0.55	0.51	0.17	0.24	0.25
SEm (±)	0.11	0.12	0.07	0.05	0.12	0.10	0.14	0.12	0.04
CD (P=0.05)	0.35	NS	0.24	0.16	NS	NS	0.45	0.39	0.14
Rice + soybean - tomato (CS 2)									
FYM	2.18	1.85	1.63	1.20	1.55	1.45	13.32	9.0	31.9
Vermicompost	1.95	1.64	1.52	0.97	1.55	1.40	8.96	6.38	28.9
Local compost	1.30	1.45	1.35	0.89	1.48	1.30	5.21	5.14	25.4
Combined source	2.08	2.41	1.91	1.12	1.61	1.49	7.91	7.67	29.4
Control	0.76	0.89	0.92	0.48	0.47	0.51	2.42	3.32	1.98
SEm (±)	0.09	0.09	0.07	0.08	0.06	0.07	0.06	0.07	0.82
CD (P=0.05)	0.31	NS	0.22	NS	0.20	NS	0.19	0.23	2.6

Similar influence of mix sources of organic manures on productivity has also been reported by Handayanto *et al*. (1997). Soybean yield as intercrop was also maximum in CSN under cropping system CS1 and CS2 (Table 1); whereas, FYM produced highest seed yield of soybean in the cropping system CS3 and CS4 (Table 2.). The fruit yield of tomato and green pod yield of French bean was maximum with FYM followed by CSN in all three years. Maximum average yield of 16.29 tonnes/ha and 7.47 tonnes/ha of tomato and French bean, respectively, were recorded with FYM as nutrient source. The yield of succeeding crop groundnut after maize was also maximum with FYM whereas; average yield of rapeseed after rice was the highest under CSN. The groundnut pod yield was maximum under FYM followed by CSN and VC. The productivity of most of the crops was consistently higher under FYM compared to other organic sources. Consistently higher yield of crops under FYM from a long term study compared to other organic sources has been also reported by Efthimiadou *et al*. (2010). Bulky nature of FYM might have helped in improving physical properties of the soil such as water holding capacity, bulk density etc. compared to other sources (Hazarika *et al*. 2006); that can have beneficial effect on soil chemical and biological parameters (Efthimiadou *et al*.

Table 2 Crop productivity (tonnes/ha) as influenced by maize based cropping systems and nutrient sources

Nutrient source	*Kharif* crop (Maize)			Intercrop (Soybean)			*Rabi*/pre-*kharif* (Groundnut/French bean)		
	2006-07	2007-08	2008-09	2006-07	2007-08	2008-09	2006-07	2007-08	2008-09
Maize + soybean-groundnut (CS 3)									
FYM	4.73	3.65	3.22	1.02	1.52	1.21	3.32	3.10	3.20
Vermicompost	4.23	3.35	3.15	0.91	1.27	1.13	2.87	2.44	2.80
Local compost	2.59	2.46	3.0	0.76	1.17	1.11	2.04	2.13	2.14
Combined source	4.20	3.58	3.29	0.96	1.28	1.19	2.13	2.36	3.30
Control	0.67	2.11	1.63	0.45	0.45	0.49	1.60	1.16	1.46
SEm (±)	0.11	0.09	0.07	0.03	0.11	0.03	0.13	0.10	0.05
CD *(P=0.05)*	0.37	0.28	0.23	0.10	NS	0.08	0.41	0.30	0.14
Maize + soybean – French bean (CS 4)									
FYM	4.58	3.75	3.39	1.09	1.28	1.19	5.24	7.60	8.6
Vermicompost	3.94	2.89	2.81	0.96	1.12	1.03	3.51	6.77	7.93
Local compost	2.49	2.39	2.54	0.82	0.93	1.0	2.83	2.78	3.49
Combined source	4.01	3.69	3.56	1.07	1.11	1.04	3.29	6.64	8.64
Control	0.46	2.03	1.44	0.50	0.49	0.42	1.06	0.83	1.04
SEm (±)	0.16	0.06	0.10	0.047	0.046	0.04	0.24	0.28	0.31
CD *(P=0.05)*	0.53	0.28	0.32	0.156	0.149	NS	0.74	0.87	0.94

Table 3 Maize equivalent yield and returns as influenced by cropping systems and nutrient sources

Treatment	Maize equivalent yield (tonnes/ha)				Prevailing price			20 % Premium price		
	2006-07	2007-08	2008-09	Pooled	Gross returns (₹/ha)	Net return (₹/ha)	B:C ratio	Gross returns (₹/ha)	Net return (₹/ha)	B:C ratio
Cropping systems										
Rice + soybean - rapeseed	7.87	9.09	4.81	7.26	54607	–2183	0.96	65528	8738	1.15
Rice + soybean-tomato	12.90	13.57	31.06	19.18	78823	7473	1.10	94588	23238	1.33
Maize + soybean-groundnut	13.13	15.17	9.98	12.76	97512	32382	1.50	117014	51884	1.80
Maize + soybean-French bean	14.18	15.79	13.33	14.43	145369	72839	2.00	174443	101913	2.41
SEm (±)	0.39	0.35	0.47	0.40						
CD *(P=0.05)*	1.25	1.12	1.47	1.21						
Nutrient sources										
FYM	16.79	17.24	17.73	17.25	119983	50073	1.72	143980	33352	1.37
Vermicompost	13.96	15.04	16.46	15.15	103354	12681.5	1.14	124025	35521	1.66
Local compost	9.61	11.89	13.35	11.62	74265	20667.5	1.39	89118	73608	2.00
Combined nutrient source	15.03	16.81	18.11	16.65	122723	49063	1.67	147268	3067	1.07
Control	4.71	6.06	8.32	6.36	39564	–4846	0.89	47477	8738	1.15
SEm (±)	0.42	0.41	0.20	0.37						
CD *(P=0.05)*	1.34	1.30	0.64	1.18						

Note: Unit price of FYM- ₹ 600/tonne, Vermicompost - ₹ 2 500/tonne, Local compost - ₹ 500/tonne, ₹ 100/man-day

2010). The influence of sources of organic manures and crop rotation on yields and crop quality has been also reported by Ramesh *et al*. (2008).

System productivity

The system productivity in terms of MEY was significantly higher in maize + soybean – French bean cropping system during 2006-07 and 2007-08 whereas, in 2008-09, rice + soybean – tomato cropping system produced higher MEY compared to other cropping systems (Table 3). The pooled MEY was the highest under rice + soybean – tomato (19.18 tonnes/ha) sequence followed by maize + soybean – French bean (14.43 tonnes/ha). Among the nutrient sources, FYM produced maximum MEY in first year (2006-07) and second year (2007-08) whereas, in the third year (2008-09), CSN produced the highest MEY followed by FYM. During 2008-09, the highest MEY was recorded with CSN (18.11 tonnes/ha) but it was at par with FYM (17.73 tonnes/ha). Pooled data indicated that FYM as source of nutrient supply produced maximum MEY (17.25 tonnes/ha) followed by CSN (16.65 tonnes/ha) and VC (15.15 tonnes/ha.). These results corroborate the findings of Kumar *et al.* (2012).

Nutrient uptake

Among the cropping systems, maximum total N, P and K uptake were recorded with maize + soybean – groundnut (CS3) followed by rice + soybean – rapeseed (CS1) (Fig 1). The highest total N and K uptake was recorded with FYM as nutrient source followed by CSN, whereas, total P uptake was maximum under CSN (Fig 2). However N, P and K uptake under FYM and CSN were at par with each other. Stein-Bachinger and Werner (1997) also observed large effect on yields and nutrient uptake due to different manures within a crop rotation. The nutrient uptake is directly correlated with yield and biomass production of crops and nutrient content in them (Patel *et al.* 2012).

Soil fertility

After 3 cropping cycles, maximum SOC (2.5 %), available N (247.2 kg/ha), P (22.70 kg/ha) and K (247.6 kg/ha) were registered under CSN compared to other sources, which were 47.2, 24.9, 54.4 and 33.3 % respectively, higher compared to that under control (Table 4). Minimum bulk density (ρ_b) was recorded with FYM (1.11 Mg/m^3) followed by CSN (1.12 Mg/m^3), VC (1.12 Mg/m^3) and local compost (1.13 Mg/m^3) as sources of nutrient supply. However, these amendments were at par with each other with respect to ρ_b. Data on DHA and SMBC of soil after 3 cropping cycles indicated the highest values under CSN followed by FYM and VC. Among the cropping systems, maize + soybean – groundnut recorded maximum available N, K and enzyme DHA while maximum available P and SMBC was recorded under Maize + soybean – Frenchbean system. Mixing manures of different origin has the potential to synchronize mineralization with crop demands and enhance productivity (Handayanto *et al*. 1997) although the practicalities of this on a farm scale are questionable (Efthimiadou *et al*. 2010). Mader *et al*. (2002) also reported higher microbial activity and MBC in organic soils than that under other sources. Continuous applications of organic amendments were reported to improve the SOC, available P and K in soil, thereby sustaining the soil health (Panwar *et al*. 2010). Increase in SOC due to organic farming has been also reported by several researchers (Babhulkar *et al*. 2000; Stolze *et al*. 2000).

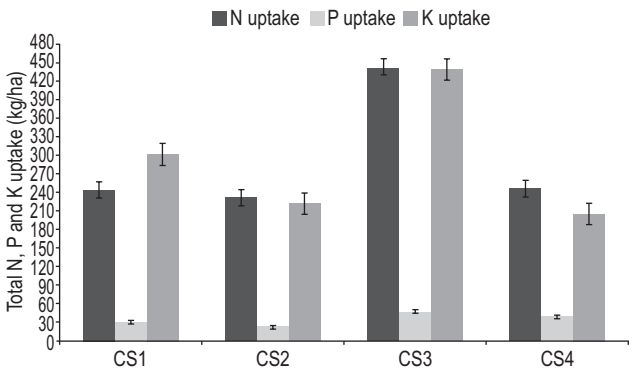

Fig 1 Total N, P and K uptake (kg/ha) as influenced by cropping systems (3 years mean) (vertical bars indicates CD at P = 0.05)

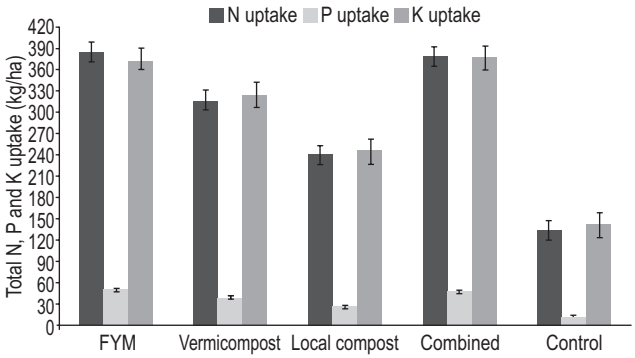

Fig 2 Total N, P and K uptake (kg/ha) as influenced by cropping sources of nutrient supply (3 years mean) (vertical bars indicates CD at P = 0.05)

Economics

Maize based cropping systems gave higher gross returns, net returns and benefit cost (B:C) ratio compared to rice based systems (Table 3). Among maize based systems, maize + soybean – Frenchbean recorded higher net returns and B:C ratio in comparison to maize + soybean – groundnut. The increase in farmers' income due to inclusion of vegetables in cropping system has been also reported by Das *et al*. (2008). A negative economic return (-2183) and B:C ratio (0.96) was observed under rice + soybean – rapeseed system. This was mainly due to lower gross return from this system owing to high cost involvement for organic manure at prevailing price. Among the nutrient sources, FYM as organic amendment gave the highest net returns (₹ 50 073.00/ha) and B:C ratio (1.72). Hence, for better return, the organic manure

Table 4 Soil properties as influenced by cropping systems and nutrient sources (after 3 cropping cycles)

Treatments	Bulk density (MG/M^3)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	SOC (%)	SMBC (µg/g dry soil)	DHA (µg/g TPF)
Cropping systems							
Rice + soybean - rapeseed	1.12	220.5	15.5	229.6	1.9	178.1	41.3
Rice + soybean - tomato	1.15	225.8	16.9	232.5	2.1	179.0	47.8
Maize + soybean - groundnut	1.13	237.6	16.9	235.3	2.2	176.2	50.6
Maize + soybean - French bean	1.12	232.3	19.2	233.6	2.2	179.3	49.5
SEm (±)	0.01	1.34	0.26	1.37	0.03	0.70	2.06
CD (P=0.05)	NS	4.3	0.82	4.4	0.08	2.20	6.47
Nutrient sources							
FYM	1.11	239.6	20.5	242.3	2.3	188.3	56.7
Vermicompost	1.12	226.8	16.4	230.4	2.0	174.7	46.6
Local compost	1.13	216.6	15.7	220.0	1.9	165.1	39.1
Combined source	1.12	247.2	22.7	247.6	2.5	202.4	64.4
Control	1.17	202.4	10.4	217.1	1.7	160.3	29.7
Initial level	1.19	185.6	10.4	165.1	1.32	157.4	32.6
SEm (±)	0.016	1.20	0.41	1.08	0.03	0.90	2.12
CD (P=0.05)	0.050	3.8	1.3	3.4	0.09	2.8	6.9

has to be produced within the farm. A premium price of at least 20 % is envisaged for assured income from organic production. Thus, premium price, which compensates for the higher cost of cultivation, sometimes lower yields under organic farming compared to that under conventional farming is required for organic farming to be a viable enterprise (Kumara and Biswas 2010).

Hence, it could be concluded that maize + soybean - French bean cropping system gave higher equivalent yield and income compared to other cropping systems. FYM alone or combined nutrient source involving 1/3 each of FYM, LC and VC on N-equivalent basis could sustain productivity, soil health and gave higher returns.

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