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Efficacy of Organically Managed Cropping System in Improvement of Soil Health in Ne Hill Region

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A B S T R A C T

Field experiments were conducted during the *kharif* seasons of 2015 and 2016 to evaluate the efficacy of the organically managed cropping system in improvement of soil health in NE hill region. Four combinations of two cropping systems (C), viz., rice-greengram (C1) and maize-greengram (C_2) and two organic N management treatments (N), viz., 75 % RD through vermicompost (N_1) and 100 % RD through vermicompost (N2) and two organic phosphorus management treatments (P) viz., 75 % RD through vermicompost (P_1) and 100 % RD through vermicompost (P_2), which was applied to succeeding crop of greengram after the main *kharif* crops, were evaluated under the trial in split plot design. Yield and yield attributing characteristics of greengram viz., no. of pods/plant, no. of seeds/pod, test weight, seed yield, stover yield and harvest index (HI) were found to be significantly higher under cropping system C_2 and organic nutrient management treatments N_2 and P_2 during both the years. Maximum rice and maize equivalent yield of greengram was also recorded under the cropping system C_2 and organic nutrient treatments N_2 and P_2 during both years. Significant increase in soil organic C, pH, available N, P_2O_5 and K_2O both before sowing and after harvest of first (rice and maize) and second (greengram) *kharif* crops was recorded under the cropping system C2 and organic nutrient management treatments N_2 and P_2.

Introduction

The agricultural production system in the NE hill region is pre-dominantly rainfed and mono-cropped at subsistence level. Slash and burn agriculture is still practiced in almost all the states on steep slopes with reduced cycle of 2-3 years against 10-15 years in the past. Thus, in the north eastern hill region, crop production is subjected to adverse and harsh geo-physical and agro-climatic conditions. Cropping system in the NE hill region is also predominantly rice based with little exception in the state of Sikkim where maize is the main food crop. Rice cultivation in the region is under low-input low-risk and low yield condition. In order to make the region self-sufficient in food grain production, the

productivity of rice and maize has to be increased from the present level. Rice is also cultivated in Jhum under zero input supply and gives very low yield (1-1-1.5 tha^{-1}). The productivity of rice in the state of Tripura (2.3 t ha^{-1}) and Manipur (2.5 t ha^{-1}) are higher than the national average, whereas all other states have lower productivity compared to national average (Das *et al.*, 2011). In case of maize, the state of Manipur (2.2 t ha^{-1}), Mizoram (1.8 t ha^{-1}) and Nagaland (2 t ha^{-1}), has comparatively better productivity than national average (Das *et al.*, 2011). Simply by adopting low cost agro-techniques like improved variety, proper time of sowing, intercultural practices, effective recycling of resources etc, yield can be increased significantly. In the present scenario of degradation of natural resources, the value of pulses is far more important. Pulses are nutritious food, feed and forage and is an integral component of subsistence cropping systems.The beneficial effect of pulse crops in improving soil health and sustaining productivity has long been realized. Due to qualitative changes in physical, chemical and biological properties, on account of biological nitrogen fixation, addition of considerable amount of organic matter through root biomass and leaf fall, deep root systems, mobilization of nutrients, protection of soil against erosion and improving microbial biomass, soil stay productive and alive. It is, therefore, imperative that grain legumes are given a preference in cropping systems of both irrigated and dryland areas.Farming in the north-east hill region is regarded as organic by default as the application of fertilizers and pesticides is meagre in these parts compared to the other parts of the country. However, with increasing population and reducing production and productivity of traditional systems of crop production in this region, there is need to increase the cropping intensity and convert subsistence agriculture into a sustainable form like organic agriculture. Organic agriculture is one among the broad-spectrum production methods that are supportive of the environment (Ramesh *et al.*, 2010). Hence, the present investigation was conducted to study the efficacy of organically managed cropping system in improvement of soil health in NE hill region

Materials and Methods

The present investigation was carried out during the *kharif* seasons of 2015 and 2016 at the experimental farm of ICAR, Nagaland Centre, Medziphema. The climatic condition of the experimental area is sub-tropical humid with annual average rainfall of 1500 mm to 2000 mm which is mainly received from April to October the remaining months being generally dry. The mean summer temperature ranges between 19^{o} C to 35^{o} C, while in winter it rarely goes below 5^{o}C. The soil of the experimental field was sandy loam in texture with pH 4.84, organic carbon (0.47%), N (147.39 kg ha^{-1}), P_2O_5 (19.04 kg ha^{-1}) and K_2O (170.02 kg ha^{-1}). The experiment was laid out in split plot design with three replications. The main treatment included 4 combinations of two cropping systems (C), *viz*., rice-greengram (C_1) and maize-greengram (C_2) and two organic N management treatments (N), *viz*., 75 % RD through vermicompost (N_1) and 100 % RD through vermicompost (N_2) whereas sub plot treatments included two organic phosphorus management treatments (P) viz., 75 % RD through vermicompost (P_1) and 100 % RD through vermicompost (P_2) which was applied to succeeding crop of greengram after the main *kharif* crops. Combinations of main plot treatments are as follows, C1N1, C1N2, C2N1 and C2N2. Upland rice variety Inglonkiri, composite maize variety 'RCM-76' and green gram variety 'Pratap (SG-1)' were used for the present investigation. For *kharif* rice and maize the experimental plot was ploughed thoroughly with tractor drawn disc plough and disc harrow followed by laddering

to obtain fine tilth and a levelled bed suitable whereas, for the following *kharif* greengram crop, the individual plots were hoed immediatedly after the harvest of the *kharif* crops and each individual plots, which were considered as main plots, were split into two sub-plots by constructing ridges 20 cm high and 30 cm wide. For organic N and P management through vermicompost the quantities of vermicompost required for organic N and P management were calculated based on based on following recommended nutrient doses viz., rice - 40 kg ha^{-1}, maize- 60 kg ha^{-1} and greengram- 35 kg ha^{-1}. Yield attributes of green gram viz. number of pods/plant, seeds/pod, test weight, seed yield, stover yield and harvest index and rice and maize equivalent yields of greengram were recorded to access the response of the crop to the different management practices. Soil nutrient status viz., soil organic C (%), pH, available N, P_2O_5 and K_2O were also recorded before and after harvest of each crop to evaluate the efficacy of the different treatments on soil health.

Results and Discussion

Yield and yield attributing characters of greengram

The effect of the main plot factors viz., cropping systems (C) and organic N management (N) on the yield attributing characteristics of greengram were found to be significant (Table 1 and 2). Significantly higher number of pods/plant, seeds/pod, test weight, seed yield, stover yield and harvest index (HI) of green gram were recorded under maize-greengram system (C_2) as compared to rice-greengram system (C_1). Application of 100 % N through vermicompost (N_2) was also found to record significantly higher yield and yield attributes of greengram during both the years compared to application of 75% N as vermicompost (N_1). The effect of sub plot factors viz., organic phosphorous management (P) was also found to record significant variations in yield and yield attributes of green gram (Table 1). The data revealed that application of 100 % P through vermicompost (P_2) in greengram resulted in significantly more number of pods/plant, number of seeds/pod, test weight, seed yield, stover yield and HI as compared to the treatment P_1 (75 % P through vermicompost) during both years.

Rice equivalent yield of greengram

Data presented in Table 3 shows the rice equivalent yield (q ha^{-1}) of greengram as affected by cropping systems, organic N management and organic phosphorus management.

The main plot factors significantly influenced the rice equivalent yield of greengram during both the years. It was recorded that significantly higher rice equivalent yield of greengram was obtained from maize-greengram system (C_2) as compared with rice-greengram system (C_1). Application of 100 % N through vermicompost (N_2) was found to record significantly higher rice equivalent yield of greengram during both the years compared to application of 75% N as vermicompost (N_1). Application of organic phosphorus in greengram also showed significant influence on the rice equivalent yield of greengram during both the years. It was found that the application of 100 % P through vermicompost (P_2) in greengram resulted in higher rice equivalent yield of greengram during both the years compared to application of 75 % P through vermicompost (P_1).

Maize equivalent yield of greengram

The effect of cropping systems, organic N management and organic phosphorus management on maize equivalent yield (q

ha^{-1}) of greengram are presented in Table 3. The main plot factors significantly influenced the maize equivalent yield of greengram during both the years. It was recorded that significantly higher maize equivalent yield of greengram was obtained from maize-greengram system (C_2) as compared with rice-greengram system (C_1).

It was also revealed that the application of 100 % N through vermicompost (N_2) recorded significantly higher maize equivalent yield of greengram compared to the application 75 % N through vermicompost (N_1). Application of organic phosphorus in greengram showed significant influence on the maize equivalent yield of greengram during both the years. It was found that the application of 100 % P through vermicompost (P_2) in greengram resulted in higher maize equivalent yield compared to the application of 75 % P through vermicompost (P_1).

Soil nutrient status before sowing and after harvest of first *kharif* crop rice and maize

Significant variations were observed with respect to soil organic C, pH, available N, P_2O_5 and K_2O recorded before and after harvest of rice and maize (Table 4 and 5). Cropping system was found to record significant effect on the soil organic C and available N, P_2O_5 and K_2O in soil after harvest of the first *kharif* crops (rice and maize).

Significantly higher soil organic C and available N, P_2O_5 and K_2O was recorded with C_2 (maize-greengram) during 2016 however, it was found to be *at par* with C_1 (rice-greengram) during 2015 in case of available N and K_2O. During the year 2016, before sowing of first *kharif* crop all soil parameters viz., soil organic C, pH and available N and P_2O_5 showed significant differences except for available K_2O which was found to be at par for both $C_1$and C_2. Organic nitrogen management (N) was also found to record significant variations with respect to soil organic C and available N and P_2O_5 both before sowing and at harvest of first *kharif* (rice and maize) during 2016. It was observed that significantly higher soil organic C, available N and P_2O_5 in soil were recorded with application of 100 % N through vermicompost (N_2) compared with N_1 (75 % N through vermicompost) however, during 2015 after harvest and 2016 before sowing both N_1 and N_2 were found to be at par with respect to soil available K_2O.

Soil nutrient status before sowing and after harvest of second *kharif* crop greengram

Cropping systems, organic nitrogen management and organic phosphorous management were found to record significant differences with respect to the different soil parameters both before sowing (after harvest of rice and maize) and after harvest of second *kharif* crop greengram during both years (Table 6 and 7). During both years, it was observed that soil organic C, pH, available N, P_2O_5 and K_2O of soil both before sowing and after harvest of greengram was significantly higher in case of maize-greengram system (C_2) as compared to rice-greengram system(C_1).

Organic nitrogen management N_2 (100 % N through vermicompost) also showed significantly higher soil organic C, pH, available N, P_2O_5 and K_2O before sowing and after harvest of greengram as compared to N_1 (75 % N through vermicompost) during both the years. With regard to organic phosphorous management, during both years it was also observed that significantly higher organic C, pH, available N, P_2O_5 and K_2O was recorded from the application of 100 % P through vermicompost (P_2) as compared to application of 75 % P through vermicompost (P_1) both before sowing and after harvest of greengram.

Table.1 Effect of cropping system, organic N and weed management on yield parameters of greengram

Treatment	Number of pods/plant		Number of seeds/pod		Test weight (g)	
	2015	2016	2015	2016	2015	2016
Cropping system (C)						
C_1-Rice-greengram	28.701	23.032	9.848	7.552	34.392	31.372
C_2-Maize-greengram	31.331	26.784	10.162	8.326	35.767	32.762
Organic N management in 1st kharif crop (N)						
N_1- 75% N as vermicompost	28.749	23.888	9.787	7.711	34.216	31.199
N_2-100% N as vermicompost	31.283	25.928	10.224	8.137	35.943	32.935
SEm (±)	0.763	0.602	0.144	0.139	0.512	0.516
CD (P=0.05)	1.634	1.288	0.309	0.297	1.095	1.105
Organic P management in 2nd kharif crop (P)						
P_1- 75% P as vermicompost	27.723	22.890	9.677	7.611	33.851	30.838
P_2- 100% P as vermicompost	32.309	26.926	10.334	8.237	36.309	33.295
SEm (±)	0.412	0.526	0.197	0.127	0.395	0.439
CD (P=0.05)	0.874	1.127	0.417	0.272	0.838	0.939
Interactions	NS	NS	NS	NS	NS	NS
CV (%)	8.811	8.370	5.001	6.074	5.051	5.576
	4.757	7.322	6.814	5.565	3.903	4.739

NS- Not significant

Table.2 Effect of cropping system, organic N and P management on yield parameters of greengram

Treatment	Seed yield (q ha^{-1})		Stover yield (q ha^{-1})		Harvest Index (%)	
	2015	2016	2015	2016	2015	2016
Cropping system (C)						
C_1-Rice-greengram	9.218	6.782	19.307	17.010	29.716	27.730
C_2-Maize-greengram	9.542	7.497	22.262	19.376	32.282	28.648
Organic N management in 1st kharif crop (N)						
N_1- 75% N as vermicompost	9.164	6.871	20.383	17.770	30.294	27.786
N_2-100% N as vermicompost	9.595	7.408	21.186	18.616	31.704	28.591
SEm (±)	0.124	0.144	0.379	0.284	0.422	0.365
CD (P=0.05)	0.265	0.307	0.810	0.609	0.903	0.782
Organic P management in 2nd kharif crop (P)						
P_1- 75% P as vermicompost	8.984	6.719	19.922	17.463	29.626	27.291
P_2- 100% P as vermicompost	9.775	7.560	21.648	18.923	32.372	29.087
SEm (±)	0.150	0.121	0.503	0.390	0.483	0.383
CD (P=0.05)	0.317	0.260	1.067	0.835	1.023	0.820
Interactions	NS	NS	NS	NS	NS	NS
CV (%)	4.581	6.967	6.304	5.416	4.718	4.488
	5.523	5.890	8.383	7.429	5.393	4.709

NS- Not significant

Table.3 Effect of cropping system, organic N and P management on rice and maize equivalent yield of greengram

Treatment	Rice equivalent yield (q ha^{-1})		Maize equivalent yield (q ha^{-1})	
	2015	2016	2015	2016
Cropping system (C)				
C_1-Rice-greengram	30.725	22.607	21.104	15.651
C_2-Maize-greengram	31.805	24.809	21.903	17.301
Organic N management in 1st kharif crop (N)				
N_1- 75% N as vermicompost	30.547	22.722	21.032	15.856
N_2-100% N as vermicompost	31.983	24.694	21.975	17.096
SEm (±)	0.413	0.488	0.204	0.331
CD (P=0.05)	0.885	1.044	0.437	0.709
Organic P management in 2nd kharif crop (P)				
P_1- 75% P as vermicompost	29.947	22.287	20.594	15.506
P_2- 100% P as vermicompost	32.583	25.129	22.413	17.466
SEm (±)	0.499	0.401	0.379	0.280
CD (P=0.05)	1.067	0.859	0.811	0.599
Interactions	NS	NS	NS	NS
CV (%)	4.581	7.126	3.292	6.967
	5.523	5.864	6.106	5.890

NS- Not significant

Table.4 Soil nutrient status before sowing of first *kharif* crops (rice and maize) during 2016

Treatment	OC (%)	pH	Available N (kg ha^{-1})	Available P_2O_5(kg ha^{-1})	Available K_2O (kg ha^{-1})
Cropping system (C)					
C_1-Rice-Greengram	0.604	5.503	259.318	31.355	147.702
C_2-Maize-Greengram	0.626	5.577	263.384	33.799	150.578
***Organic N management during 1st kharif crop* (N)**					
N_1- 75% N as vermicompost	0.603	5.496	259.013	31.361	147.727
N_2- 100% N as vermicompost	0.625	5.581	263.689	33.801	150.553
SEm (±)	0.004	0.019	0.089	0.444	0.921
CD(P=0.05)	0.020	0.084	4.010	1.988	4.144
Interaction	NS	NS	NS	NS	NS
CV (%)	2.461	1.167	1.182	4.723	2.139

NS- Not significant

Table.5 Soil nutrient status after harvest of 1st*kharif* crops (rice and maize)

Treatment	OC (%)		pH		Available N (kg ha^{-1})		Available P_2O_5 (kg ha^{-1})		Available K_2O (kg ha^{-1})	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Cropping system (C)										
C_1-Rice-Greengram	0.525	0.620	5.207	5.541	253.652	265.988	22.093	33.355	129.767	159.535
C_2-Maize-Greengram	0.539	0.640	5.298	5.619	258.539	270.578	23.923	35.799	133.878	162.361
Organic N management during 1st kharif crop (N)										
N_1- 75% N as vermicompost	0.526	0.622	5.205	5.540	253.657	265.873	22.095	33.355	129.836	159.560
N_2- 100% N as vermicompost	0.541	0.642	5.300	5.631	258.534	270.693	23.922	35.799	133.808	162.336
SEm (±)	0.002	0.004	0.025	0.017	1.592	0.841	0.326	0.458	1.287	0.825
CD(P=0.05)	0.010	0.018	0.111	0.078	7.165	3.785	1.465	2.060	5.790	3.713
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	1.481	2.154	1.633	1.075	2.154	1.086	4.901	4.586	3.381	1.920

NS- Not significant

Table.6 Soil nutrient status before sowing of second *kharif* crop greengram

Treatment	OC (%)		pH		Available N (kg ha^{-1})		Available P_2O_5 (kg ha^{-1})		Available K_2O (kg ha^{-1})	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Cropping system (C)										
C_1-Rice-greengram	0.540	0.609	5.274	5.510	250.935	256.535	23.822	32.427	129.517	163.933
C_2-Maize-greengram	0.556	0.633	5.300	5.590	258.187	263.683	25.048	33.512	138.464	172.756
Organic N management in 1st kharif crop (N)										
N_1- 75% N as vermicompost	0.539	0.614	5.269	5.522	252.452	258.879	23.997	32.457	132.746	167.246
N_2-100% N as vermicompost	0.556	0.628	5.305	5.568	256.670	261.340	24.894	33.483	135.235	169.443
SEm (±)	0.004	0.004	0.008	0.013	1.302	0.783	0.232	0.233	1.139	1.014
CD (P=0.05)	0.012	0.009	0.025	0.039	2.785	1.677	0.496	0.498	2.437	2.169
Organic P management in 2nd kharif crop (P)										
P_1- 75% P as vermicompost	0.538	0.609	5.248	5.518	252.259	257.565	23.461	31.919	131.718	165.718
P_2- 100% P as vermicompost	0.557	0.633	5.326	5.583	256.863	262.653	25.410	34.020	136.263	170.971
SEm (±)	0.004	0.004	0.011	0.013	1.564	0.856	0.200	0.205	0.869	0.662
CD (P=0.05)	0.011	0.009	0.034	0.039	3.316	1.832	0.428	0.438	1.841	1.416
Interactions	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	3.651	2.413	0.766	1.144	1.771	1.043	3.288	2.446	2.944	2.086
	3.341	2.271	1.054	1.148	2.128	1.140	2.833	2.150	2.245	1.361

NS - Not significant

Table.7 Soil nutrient status after harvesting of second *kharif* crop greengram

Treatment	OC (%)		pH		Available N (kg ha^{-1})		Available P_2O_5 (kg ha^{-1})		Available K_2O (kg ha^{-1})	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Cropping system (C)										
C_1-Rice-greengram	0.578	0.716	5.380	5.760	258.698	265.433	33.704	38.150	157.860	169.855
C_2-Maize-greengram	0.595	0.736	5.429	5.840	266.127	272.211	38.156	39.723	163.038	174.618
Organic N management in 1st kharif crop (N)										
N_1- 75% N as vermicompost	0.580	0.719	5.381	5.781	260.743	267.568	35.275	38.301	158.695	169.152
N_2-100% N as vermicompost	0.595	0.733	5.429	5.821	264.081	270.076	36.585	39.522	162.202	171.320
SEm (±)	0.004	0.003	0.013	0.013	0.908	0.789	0.295	0.253	1.514	1.008
CD (P=0.05)	0.013	0.007	0.039	0.039	1.944	1.689	0.630	0.541	3.240	2.157
Organic P management in 2nd kharif crop (P)										
P_1- 75% P as vermicompost	0.576	0.714	5.352	5.768	259.221	266.450	34.533	37.783	157.473	167.599
P_2- 100% P as vermicompost	0.597	0.738	5.458	5.833	265.604	271.194	37.327	40.040	163.424	172.873
SEm (±)	0.004	0.003	0.012	0.013	1.580	0.951	0.282	0.240	1.320	0.644
CD (P=0.05)	0.014	0.006	0.036	0.039	3.381	2.035	0.597	0.514	2.799	1.378
Interactions	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	3.582	1.489	1.177	1.095	1.199	1.017	2.840	2.250	3.269	2.051
	3.749	1.378	1.075	1.098	2.085	1.226	2.715	2.140	2.850	1.310

NS - Not significant

Effect on yield

Significantly higher yield performance of greengram under maize-greengram cropping system (C_2) could be due to the fact that maize being a C4 plant, comparatively lower weed growth was observed (visual) this smothering effect on weed growth may have reduced soil nutrient uptake by weeds thereby resulting in residual effect of applied nutrients for succeeding *kharif* greengram crop. It may also be noted that subsequent phosphorous management in second *kharif* crop greengram might have resulted in positive additive reaction with residual effect of first crop. whereas, under rice-greengram system it was also visually observed that owing to smaller stature of rice plant weed growth was comparatively higher which may have led to increased removal of applied nutrients resulting in sub optimal availability of residual nutrient and yield of succeeding greengram crop. Higher yield, yield attributes of greengram and rice and maize equivalent yields recorded by the systems under the treatments N_2 and P_2 may be attributed to the fact that optimum doses of nitrogen under N_2 applied through vermicompost to the preceding *kharif* crops (rice and maize) may have resulted in residual carry-over of nutrients to the succeeding *kharif* greengram this, coupled with optimum phosphorous application (P_2) might have boosted the yield performance of greengram and the equivalent yields of the systems. The significant residual effect of vermicompost application on the succeeding greengram and other crops on yield and yield attributes were also reported by Faujdar and Sharma (2013), Dey and Paul, (2013), Pate *et al.,* (2014) and Alagappan and Venkitaswamy (2016). The efficacy of vermicompost application on increasing the yield of greengram was also reported by Rajkhowa *et al.,* (2002), Bhatt *et al.,* (2012) and Sushil *et al.,* (2015), which confirms to the findings of the present investigation.

Effect on soil health

The findings on the effect of treatments on the soil nutrient status suggests that there was a significant effect on all the crops in sequence with regard to organic C, pH and available N, P_2O_5 and K_2O content in the soil. Significantly higher build-up of soil organic C, pH and available N, P_2O_5 and K_2O under maize-greengram sequence as observed under both first and second *kharif* crop may be due to the fact that maize crop could significantly supress the weed population thereby resulting in lesser uptake of soil nutrients by the weeds as compared to rice-greengram sequence. The application of 100% N and P through vermicompost showed significant influence which resulted in higher soil organic C, pH and available N, P_2O_5 and K_2O content as compared with the application of 75 % N and P through vermicompost which may be attributed to availability of higher soil nutrients with application of 100% N and P as compared to 75 % N and P in both the crop sequence. It was observed that there was a steady built up of organic C, pH and available N, P_2O_5 and K_2O content both before sowing and after harvest of greengram crop during both the years. This may be due to combined effect of vermicompost in the first *kharif* crop (rice and maize) followed by application of vermicompost in the second *kharif* crop (greengram) which may have increased their availability and subsequent build. These findings of the present investigation corresponds to the findings conducted by Parthasarathi *et al.,* (2003), Rajkhowa *et al.,* (2002), Singh *et al.,* (2005), Jayaprakash *et al.,* (2004), Parthasarathi *et al.,* (2008), Ramesh *et al.,* (2010), Porpavai *et al.,* (2011), Vidyavathi *et al.,* (2011), Tharmaraj *et al.,* (2011), Kachroo *et al.,* (2014), Choudhary and Kumar (2013), where they reported that application of vermicompost increased the organic C, pH, N, P_2O_5 and K_2O content in the soil. They also reported that with the

increase in the level of vermicompost, the soil organic C, pH, N, P_2O_5 and K_2O content tends to increase.

From the findings of the present investigation it may be concluded that organic management of rainfed cropping system encourages buildup of soil organic C, pH and available N, P_2O_5 and K_2O in soilthereby maintaining and improving the soil health. Maize-greengram cropping system with organic management of nutrients viz., 100% N and P through vermicompost, is a better alternative than rice-greengram cropping system under rainfed condition of north-east hill region for maximizing productivity and profitability of the system.

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