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Seasonal effect of green manure and phosphorus levels on soil parameters and their correlation in acid soils of Meghalaya

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ABSTRACT

The present investigation was carried out at the experimental farm of College of Post Graduate Studies, CAU, Meghalaya in 2012 to study the seasonal effect on soil properties as influenced by green manure and phosphorus in acid soil. In summer, the experiment was conducted for baby corn (*Zea mays* L.) with *in situ* green manuring of ricebean (*Vigna umbellata* L.) consisting of two levels *i.e.* without and with green manuring and three levels of phosphorus (P) *i.e.* 0, 30 and 60 kg P_2O_5 ha^{-1} supplied through single super phosphate. In *kharif*, the baby corn was sown with 80 kg N, 40 kg P_2O_5 and 40 kg K_2O. Bulk density (BD), porosity, organic carbon (OC), available nitrogen (N), P and soil microbial biomass carbon (SMBC), nitrogen (SMBN) and phosphorus (SMBP) were significantly influenced by green manure and phosphorus in summer. The residual green manure also enhanced the physical, chemical and microbial properties of the soil, but residual P had effect over available P only. Negative correlation existed between BD and porosity, OC, available N, P and microbial biomass in soil. Significant positive correlation ($p<0.01$) was found between OC and SMBC, N and SMBN, P and SMBP in summer and between N and SMBN ($p<0.05$) in *kharif*. Baby cob yield, fodder yield and harvest index were positively influenced by direct application of green manure and P levels. The highest yield of baby corn obtained with application of 60 kg P_2O_5 ha^{-1} was 3.64 and 2.58 t ha^{-1} in summer and *kharif*, respectively. Yield in summer was significantly positively correlated ($p<0.01$) with all the soil properties except BD.

1. INTRODUCTION

Phosphorus (P) is the second most important macro nutrient required by the plants, next to nitrogen (N) and is involved in different functions like root development and metabolic activities, particularly in protein synthesis (Tanwar and Shaktawat, 2003). Its deficiency is a major constraint in crop production in most tropical and subtropical acid soils and hence P fertilizers are required to sustain optimum crop yields (Nachimuthu *et al.,* 2009). The P fertilizers applied are fixed with aluminum and iron oxides in acid soil and is unavailable to crops which is a major factor limiting crop production. The availability of this nutrient in acid soils can be enhanced by combined use of fertilizers and green manure, due to the dissolution of sparingly soluble P sources and reduced P retention (Bah *et al.,* 2006). Green manuring is an important management practice which not only maintains the fertility status of soil (Shah *et al.,* 2003) but also reduces the use of mineral fertilizers (Elfstrand *et al*., 2007). The use of legumes as green manure crops fix atmospheric N and add to the soil N pool (Carlson and Huss-Danell, 2003). The vegetative cover reduces the runoff, conserves moisture and improves soil physical properties by increasing distribution and stability of soil aggregates and decreasing soil bulk density (Yang *et al*., 2005). Lot of studies have been done on the combined effect of organic and inorganic sources of fertilizer on the yield of crop but few have been done to study the soil microbial dynamics and its correlation with yield. Microbial biomass, being an important attribute of soil quality that provides indication of soil ability to store and recycle nutrients and energy, is an important parameter. The soil microbial biomass serves as a sink (immobilization) and source (mineralization) of important nutrients, controlling the supply of nutrients to crops through mineralization and immobilization processes (Fosu *et al.,* 2007). Determination of microbial N is important for quantification of nitrogen dynamics in agricultural ecosystems because it controls soil organic nitrogen availability and loss especially in input intensive agro-production system (Moore *et al.,* 2000). Microbial biomass P represents a small but labile pool of soil P (Tate, 1985) and is considered as an important source of phosphorus for plant uptake (Macklon *et al.,* 1997) in P fixing soil. It is regarded as an easily mineralisable fraction of soil (Redel *et al.,* 2008). Additional studies are required to improve knowledge on the changes in microbial biomass with relation to seasonal pattern. For this study, baby corn was taken as it is a short duration crop that can be taken 3-4 times a year and is more profitable than grain maize which may be helpful in raising the income of the farmers of North East region. Hence, the present investigation was carried out to study the seasonal effect of green manure and phosphorus on the correlation between physical, chemical and microbial properties of soil in baby corn based cropping system in acid soils of Meghalaya.

2. MATERIALS AND METHODS

The experiments were conducted at the Research Farm of the College of Post Graduate Studies, CAU, Umiam (situated at 91° 54.73' E and 25° 40.91' N at an altitude of 950 m above the msl), Meghalaya, India during the summer and *kharif* seasons of 2012. In this region, monsoon normally sets in during the first fortnight of June, extends up to September and withdraws by October with pre-monsoon showers from April. Average total rainfall of 2086 mm yr^{-1} was received with a high relative humidity of above 80%. The average maximum (Tmax) and minimum (Tmin) temperature recorded during summer season was 27.7°C and 14.9°C, respectively. During *kharif* season, the average Tmax and Tmin were 27.9°C and 18.4°C, respectively. The soil was acidic (pH 4.9) in nature with sandy clay loam texture, bulk density (1.4 g cc^{-1}), organic carbon (0.8%), available N (282.2 kg ha^{-1}), available P (13.0 kg ha^{-1}) and available K (242.0 kg ha^{-1}) .

The field experiments were laid out in split plot design with four replications. In summer season, the experiment was conducted for baby corn with *in situ* green manuring of ricebean (*Vigna umbellata*) comprising two levels *i.e.* without (G_1) and with green manuring (G_2) allocated to main plots and three levels of phosphorus *i.e.* 0(P_0), 30(P_1) and 60(P_2) kg P_2O_5 ha^{-1} supplied through single super phosphate (SSP) to sub plots. A common dose of nitrogen and potassium @ 80 and 40 kg ha^{-1} through urea and muriate of potash (MOP), respectively was applied to the crop. Ricebean was sown along with the baby corn on 21 February, 2012 and was incorporated at 61 DAS. In *kharif* season, baby corn was sown on 2 July, 2012 with the residual effect of green manure and P levels. A blanket application of urea, SSP and MOP @ 80, 40 and 40 kg ha^{-1}, respectively was applied. The biomass and nutrient composition of ricebean as green manure at the time of incorporation is given in Table 1.

Soil samples were collected from a depth of 0-15 cm after harvest of summer and *kharif* crops. Bulk density (BD) of soil was estimated by core method (Black, 1965). Total porosity in soil was determined by the formula [(1-(Bulk density/Particle density)]*100. Soil organic carbon (OC), available N and P were determined by wet oxidation method (Black, 1965), alkaline permanganate method (Subbiah and Asija, 1956) and Brays method (Jackson, 1973), respectively. Freshly collected soil samples were used for the determination of soil microbial biomass carbon (SMBC), soil microbial biomass nitrogen (SMBN) and soil microbial biomass phosphorus (SMBP). They were determined by chloroform fumigation extraction method (Brookes and Joergensen, 2006). The difference in carbon content between fumigated and non-fumigated soil samples was determined and then SMBC was calculated by the formula: SMBC= E_C/k_{EC}, where E_C= [(organic carbon extracted from fumigated soils) - (organic carbon extracted from non-fumigated soils)] (Vance *et al.,* 1987) and k_{EC}= 0.45 (Wu *et al.,* 1990). SMBN was calculated by the formula: SMBN= E_N/k_{EN}, where E_N= [(total N extracted from fumigated soils) - (total N extracted from non-fumigated soils)] (Brookes *et al.,* 1985) and k_{EN}= 0.54 (Jenkinson, 1988). SMBP values were calculated by the formula: SMBP= E_P/k_{EP}, where E_P [(total P extracted from fumigated soils) - (total P extracted from non-fumigated soils)] and k_{EP}= 0.40 (Brookes *et al.,* 1982). SMBC, SMBP and SMBN were expressed in $\mu g\ g^{-1}$ soil.

Main effects of green manure, P levels and interactions between these factors for their direct and residual response were tested by using the Fisher's method of analysis of variance (ANOVA) as described by Gomez and Gomez (1984). Test of significance of the treatment difference was done on the basis of 't-test' and the means were separated using least significance difference (CD) at 5% probability level. SPSS 11.5 version for windows package was used for statistical analysis.

Table: 1
Biomass and nutrient composition of ricebean at the time of incorporation (61 DAS)

Phosphorus levels	Fresh weight (t ha^{-1})	Dry weight (t ha^{-1})	N content (%)	P content (%)	K content (%)
0 kg ha^{-1} (P_0)	1.59	0.24	2.18	0.18	0.50
30 kg ha^{-1} (P_1)	2.09	0.32	2.23	0.21	0.64
60 kg ha^{-1} (P_2)	2.78	0.45	2.32	0.24	0.81

3. RESULTS AND DISCUSSION

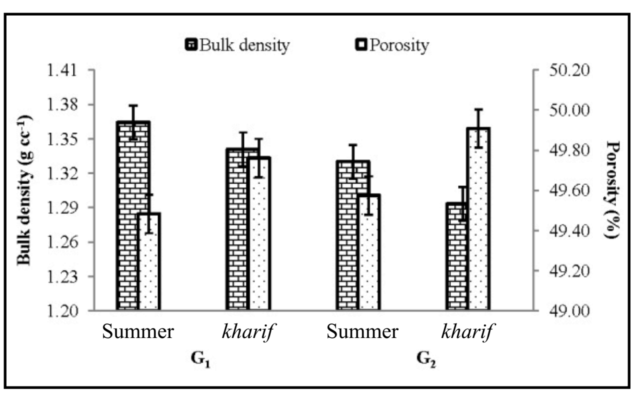
Bulk Density and Porosity

Application of green manure appreciably reduced BD by 2.5% in summer (Fig. 1) and 3.5% in *kharif* over without green manure. Highest porosity was observed with the residual green manure in *kharif* season *i.e.* 49.9% while in summer it was 49.6%. Lowering of bulk density may be attributed to organic matter decomposition and loosening of soil by root action and thereby increase in porosity (Lampurlanes and Cante-martinez, 2003). Application of green manure enhanced the soil moisture retention because of its hydrophilic nature (Annabi *et al.,* 2007).

Organic Carbon, Available N, P, K

Organic carbon (OC) content in soil was significantly influenced by both direct and residual effect of green manure. Incorporation of green manure in summer readily enhanced the OC content in soil by 24.3%, while the residual effect of green manure in *kharif* improved the OC content by 17.6% over without green manuring (Table 2). The increase in soil OC content may be due to the decomposition of green manure which released nutrients to the soil. These results are similar to those reported by Zhang *et al.* (2007). Phosphorus application in summer had remarkable effect on OC content in soil and 60 kg P_2O_5 ha^{-1} (P_2) recorded the highest value (1.0%) whereas the lowest OC content (0.7%) was observed in absence of P application (P_0).

The maximum available N (242.8 kg ha^{-1}) was observed due to green manure which was 10.1% more over without green manure (G_1) (Table 2). Green manure can mop up nitrate nitrogen and release slowly upon decomposition making it available for succeeding crop. Addition of green manure also enhanced the pH slightly hence acting as an amendment. Legume green manure fixes atmospheric N and hence increases the availability of N (Rochester *et al.,* 2001). Availability of N was more in summer which may be due to the rapid mineralization of



***Error bar with standard error**

Fig.1. Direct and residual effect of green manure on bulk density and porosity in summer and *kharif* seasons, respectively

Table: 2
Direct and residual effect of green manure and P levels on OC, available N, P, K, SMBC, SMBN and SMBP in summer and *kharif* seasons

Treatment	OC (%)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})		SMBC (µg g^{-1}soil)		SMBN (µg g^{-1}soil)		SMBP (µg g^{-1}soil)	
	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*
Green manure														
Without green manure (G_1)	0.79	0.81	220.47	200.18	10.73	8.01	230.29	178.25	389.97	338.95	50.78	51.60	11.06	12.02
With green manure (G_2)	0.98	0.95	242.79	212.15	12.55	11.77	242.37	239.57	428.35	370.22	53.87	54.93	12.82	12.89
CD (P=0.05)	0.06	0.08	17.87	NS	0.79	1.13	NS	15.08	18.96	24.61	2.18	1.27	1.56	NS
Phosphorus levels														
0 kg ha^{-1} (P_0)	0.74	0.83	221.01	198.08	10.16	9.09	224.57	197.81	371.76	351.53	49.78	51.58	8.89	11.93
30 kg ha^{-1} (P_1)	0.88	0.93	233.50	207.55	11.85	9.93	240.65	211.92	412.08	353.65	52.84	53.60	11.61	12.44
60 kg ha^{-1} (P_2)	1.04	0.89	240.39	212.88	12.92	10.64	243.76	217.00	443.64	358.58	54.35	54.61	15.32	12.98
CD (P=0.05)	0.05	NS	NS	NS	0.95	1.11	NS	NS	42.83	NS	3.60	NS	1.82	NS
Interaction (G*P)	*	-	-	-	*	-	-	-	-	*	-	*	-	-

green manure favoured by optimum temperature and moisture (Brandsaeter *et al.,* 2008).

P availability in soil was significantly influenced by direct and residual effect of green manure (Table 2). With the incorporation of green manure, the increase in available P was 16.9% in summer and 41.0% in *kharif* due to residual effect. The exudation of organic acids from the roots of ricebean must have increased the phosphate mobility in soil. This P was then more readily available after the decomposition of green manure. Hence, the availability was less in summer, but it increased in *kharif* season. A linearly rising trend of available P was observed with increase in the residual P levels *i.e.* 0, 30 and 60 kg P_2O_5 ha^{-1} (9.1, 9.9 and 10.6), respectively. Application of 60 kg P_2O_5 ha^{-1} recorded the highest biomass of ricebean as compared to 0 kg P_2O_5 ha^{-1} and hence more biomass was incorporated in plots supplied with the highest P (Table 1) indicating greater availability of P upon decomposition of green manure. Lower C:P ratio favored mineralization of green manure residues with reduced immobilization and hence enhanced the availability of P (Pypers *et al.,* 2012).

Even though there was no significant effect of green manure and P on available K but still there was a numerical increase in available K both in summer and *kharif* seasons.

SMBC, SMBN and SMBP

The direct and residual effects of green manuring significantly influenced the SMBC and SMBN in summer and *kharif* seasons, respectively (Table 2). The SMBC, SMBN and SMBP increased in green manured treatments by 9.8, 6.1 and 15.8% in summer and by 9.2, 6.5 and 7.3% in *kharif* , respectively over without green manure. Increased microbial population in soil could be due to enhanced organic matter inputs from the green manure legumes and cropping intensity (Gong *et al.,* 2009). In this study, SMBC was higher in summer months, demonstrating the storage of soil nutrients within the soil biomass as a consequence of intensive nutrient demand by plants and soil micro-organisms (Ge *et al.,* 2010). In contrast to this, the SMBN and SMBP showed a slight increase in *kharif* season as compared to summer season. Although SMBP did not show significant effect due to green manure and phosphorus, numerical increase was observed which may be due to lower temperature. The temperature was less when the analysis for microbial portions for *kharif* was performed as compared to summer season. Similar results were obtained by Perrott and Sarathchandra (1990) who also reported that the SMBN and SMBP declined at high temperature but increased at low temperature. The possible explanation given by them was that the microbial biomass stored more N in them at low temperature which led to the increase in the bacterial component of biomass relative to the fungal component as bacteria contain higher nutrient concentrations than fungi (Perrott *et al.,* 1990). With increase in P levels, the microbial activity also improved showing the positive influence of P on microbial growth. Highest SMBC (443.6 μg g^{-1}soil), SMBN (54.4 μg g^{-1}soil) and SMBP (15.3 μg g^{-1}soil) were obtained with application of 60 kg P_2O_5 ha^{-1} in summer season. The reduction can be attributed to the reduced growth of ricebean at low level of phosphorus and hence less biomass incorporated leading to reduced microbial biomass build up. Similar results were also reported by Thompson *et al.* (1992). However, residual P failed to bring significant impact on the microbial activity.

Yield

Direct application of green manure and P levels in summer appreciably influenced the baby corn cob yield, fodder yield and harvest index. Regardless of P levels, higher baby cob yield was obtained with green manuring and was 3.12 t ha^{-1} in summer, which was 1.2 times higher over without green manuring (Table 3). The incorporation of ricebean biomass released nutrients to soils, which improved the physical and chemical environment of soil and enhanced crop uptake and thereby increased crop yields (Reddy *et al.,* 2004). With increase in P levels, the yield increased significantly and comparatively higher yield was observed with direct effect in summer than residual effect in *kharif.* The residual P significantly affected the baby corn cob yield which can be explained by the fact that residual P is a highly stable part of the total P pool which is available to plants in long term only (Cross and Schlesinger, 1995).

Table: 3
Direct and residual effects of green manure and phosphorus on baby cob yield, fodder yield and harvest index in summer and *kharif*, respectively

Treatment	Baby cob yield (t ha^{-1})		Fodder yield (t ha^{-1})		Harvest index	
	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*
Green manure						
Without green manure	2.59	1.97	18.54	15.40	12.10	11.30
With green manure	3.12	2.28	20.53	17.48	13.08	11.61
CD (P=0.05)	0.18	NS	1.24	NS	0.86	NS
Phosphorus levels						
0 kg ha^{-1} (P_0)	2.19	1.87	16.84	16.14	11.48	10.52
30 kg ha^{-1} (P_1)	2.72	1.93	19.22	15.34	12.36	11.13
60 kg ha^{-1} (P_2)	3.64	2.58	22.55	17.85	13.93	12.70
CD (P=0.05)	0.21	0.44	0.96	NS	1.01	NS

Correlation

Negative correlation was found between BD and porosity with r= -0.688 ($p<0.01$) in summer (Table 4) and r= -0.463 ($p<0.05$) in *kharif* (Table 5). A significant decrease in BD with an associated increase in total porosity of soil under green manure is probably related to greater amount of organic matter deposition and loosening of soil by root action (Haynes, 2000). BD was negatively correlated with OC, available N, P, SMBC, SMBN and SMBP in both summer and *kharif* seasons. This shows that with addition of green manure and P levels there is decrease in bulk density and improvement in status of soil nutrients irrespective of seasons. Positive significant correlation ($p<0.01$) was found between OC and SMBC (r=0.682), N and SMBN (r=0.692), P and SMBP (0.743) in summer and between N and SMBN (r=0.426; $p<0.05$)) in *kharif*. The variations in OC were positively correlated with available N, P, SMBC, SMBN and SMBP ($p<0.01$) in summer season and the correlation coefficients are 0.553, 0.807, 0.682, 0.594, 0.820, respectively whereas in *kharif*, significant correlation was observed between OC and available P (r=0.507, $p<0.05$). Gomez *et al.* (2006) demonstrated a positive linear regression relating microbial diversity to soil organic carbon and suggesting that increase in functional diversity may be explained by the increase in carbon availability resulting from green manure amendments. Yield in summer was significantly positively correlated with all the soil properties except bulk density. This suggests that with increase in chemical and biological fractions the yield increased but with increase in BD, there is decrease in porosity and hence decrease in yield.

4. CONCLUSIONS

Application of green manure and phosphorus influences the activities of soil microorganisms and thereby decomposition processes occurring in soil. The organic and inorganic sources of nutrients influence the biomass and soil properties *viz.,* BD, porosity, OC, N, P, K, SMBC, SMBN and SMBP. It is concluded that the microbial biomass fractions are correlated with the physical and chemical properties of soil. Thus the judicious application of both organic and inorganic sources paves the way for improving soil environment favorably for successful crop production.

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Table: 4
Direct effect of green manure and P levels on correlation coefficient between OC, available N, P, SMBC, SMBN, SMBP, BD, porosity and yield in summer

	OC	N	P	SMBC	SMBN	SMBP	BD	POROSITY	YIELD
OC	1.000								
N	0.553**	1.000							
P	0.807**	0.594**	1.000						
SMBC	0.682**	0.407*	0.502*	1.000					
SMBN	0.594**	0.692**	0.578**	0.480*	1.000				
SMBP	0.820**	0.429*	0.743**	0.664**	0.437*	1.000			
BD	-0.631**	-0.408*	-0.648**	-0.475*	-0.331	-0.400	1.000		
POROSITY	0.282	-0.022	0.304	0.276	0.134	0.164	-0.688**	1.000	
YIELD	0.833**	0.543**	0.777**	0.684**	0.522**	0.866**	-0.514*	0.291	1.000

**Correlation is significant $p < 0.01$ and *Correlation is significant $p < 0.05$

Table: 5
Residual effect of green manure and P levels on correlation coefficient between OC, available N, P, SMBC, SMBN, SMBP, BD, porosity and yield in *kharif*

	OC	N	P	SMBC	SMBN	SMBP	BD	POROSITY	YIELD
OC	1.000								
N	0.055	1.000							
P	0.507*	0.190	1.000						
SMBC	0.321	0.212	0.550**	1.000					
SMBN	0.260	0.426*	0.403	0.483*	1.000				
SMBP	0.177	0.286	0.227	0.437*	0.159	1.000			
BD	-0.480*	-0.442*	-0.808**	-0.613**	-0.531**	-0.330	1.000		
POROSITY	-0.128	0.362	0.145	0.226	0.416*	-0.161	-0.463*	1.000	
YIELD	0.218	0.235	0.374	0.132	0.240	0.364	-0.364	0.246	1.000

**Correlation is significant $p < 0.01$ and *Correlation is significant $p < 0.05$

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