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Rock Phosphate Enriched Compost *vis-à-vis* Inorganic Fertilization: Effect on Soil Chemical and Biological Properties

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ABSTRACT

An experiment was carried out at Soil Science farm in IARI, New Delhi to assess the effect of soil amendment with rice straw enriched rock phosphate compost on chemical and biological properties as compared to mineral fertilization. The four treatments applied were *viz.* T_1: Control; T_2: Recommended dose of NPK fertilizers (100% NPK); T_3: Rice straw enriched rock phosphate compost @5t ha^{-1}; T_4: 50% NPK+ Rice straw enriched rock phosphate compost @5t ha^{-1}. The soil samples from the above treatment plots were collected at 0-15 cm soil depth and analysis were carried out for chemical and biological soil properties as per the standard procedures. The chemical parameters like mineral nitrogen [ammonical (NH_4) and nitrate (NO_3)-N], available phosphorus (P), soil organic carbon (SOC) were found to be highest in the T_4 treatment plots ($P \leq 0.05$). The soil biological properties like soil microbial biomass carbon (SMB)-C, -N and -P and enzyme activities like alkaline phosphatase (PHA), dehydrogenase (DHA), fluorescein di-acetate (FDA) and urease activity were also found to be significantly higher in integrated treatment of 50% of NPK+enriched compost plot as compared to the sole treatment either of enriched compost or inorganic fertilization. The significantly higher metabolic quotient (qCO_2) in the treatment T_2 *i.e.* 100% recommended doses of NPK (5.45 mg CO_2–Cg^{-1}Cmic h^{-1}; $P \leq 0.05$) indicate the negative effect on the microbial activity in the soils. Thus, from the present study it can be concluded that the 50% NPK+ Rice straw enriched rock phosphate compost treatment has the potential to enrich the soil with nutrients and at the same time can improved the microbial activities in the soil.

1. Introduction

In India about 160 Mt of rock phosphate (RP) deposits are available at present (FAI, 2011), most of them are low-grade because of low phosphorus(P) content (less than 20% P_2O_5) and considered unsuitable for manufacturing of conventional P-fertilizers. The alternative means of utilizing this low-grade RPs is through preparation of enriched compost using crop residues (Biswas and Narayanasamy 2006).

The addition of RP to the compost taking rice straw as raw material can increased the total P content to 3.62% comparing to the ordinary compost which is 0.46% total P (Nishanth and Biswas 2008), suggesting that the enriched compost can supplement the P requirement of crops up to certain extend reducing its dependence on commercial inorganic fertilizers. Besides this, application of compost is also known to increase the soil organic matter (SOM) content, water holding capacity and soil aggregate stability (Carrera *et al.,* 2007; Well *et al.,* 2000), which in turn have a positive effect on soil health,

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furthermore, application of compost is economical and environment friendly. Response of organic sources of nutrients like compost, FYM *etc.* and its integrated approach with inorganic sources of nutrients on crop uptake, yield and its effect on major nutrients in soil has always been studied under the intensive cropping systems (Imran *et al.,* 2011; Abedi *et al.,* 2010). However, very little information is available of these nutrient management approaches on its effect on microbial activity, active biological pools, mineral nutrients and its different fractions. Further, these parameters are considered dynamic and sensitive to the changing soil conditions and agricultural practices (Nannipieri *et al.,* 2002).

Considering the above facts, we hypothesised in the present study that the integrated management of nutrients through organic and inorganic sources may provide an efficient use of resources for maintaining soil fertility as well as biological properties like microbial biomass and enzyme activities in soil amended with enriched compost and mineral fertilization under intensive cropping system. With this background the objective of the present study was carried to assess the effect of soil amendment with rock phosphate enriched compost and mineral fertilization on soil chemical properties like mineral nitrogen (NH_4^+-N and NO_3^--N), available potassium (K) and P, total P, sequential fractionation of P; and biological properties like soil microbial biomass, enzyme activities, basal respiration (BAS) and metabolic quotient (qCO_2) under a 3-year-old wheat-green gram crop rotation.

2. Materials and Methods

The experimental site was located at the IARI Soil Science farm, New Delhi (28º37'–28º39'N latitude and 77º9'–77º11'E longitude) at an altitude of 220 m above mean sea level. The field was in the third year of its enriched compost treatment and four treatment plots selected for the study were: T_1: Control; T_2: Recommended dose of NPK fertilizers (100% NPK); T_3: Rice straw enriched RP compost @ 5t ha^{-1}; T_4: 50% NPK+ Rice straw enriched RP compost @ 5t ha^{-1}. The characteristics of rice straw RP enriched compost use in the treatment plots were pH: 7.71, ash content: 59.8 %, total organic carbon (TOC): 23.32% and total P: 2.25%. The composite soil samples from the selected plots were collected at 0-15 cm depth with three replications and one half of each sample were stored at 4˚C for analysis of microbiological parameters and other half was kept open for air drying at laboratory for chemical analysis.

Soil Chemical analysis

Olsen P in air dried soil (Olsen *et al*., 1954) was determined by following the ascorbic acid method (Watanabe and Olsen 1965) and the intensity of the blue colour were measured at 750 nm. Total P is determined by the method outlined by Walker and Adams (1958). The P content in the extracts of ignited sample was measured by ascorbic acid reduction of the ammonium phosphomolybdate complex method, as outlined by Watanabe and Olsen (1965) and the colour intensity was measured at 750 nm. Available K is determined as described by Hanway and Heidel (1952) in flame photometer. The NH_4 and NO_3-N were estimated after the soil samples were extracted with KCl at the ratio of 1:5 and NH_4^+ -N and NO_3^- -N was determined in the supernatant by the regular Kjeldahl method (Keeney and Nelson 1982) by addition of MgO for NH_4 and MgO+Devarda alloy for the NO_3-N. The SOC of the soil was determined by the wet oxidation method described by Walkley and Black (1934).

Sequential P fractionation

Soil P was fractionated into various inorganic fractions [Saloid-P, Aluminium-P (Al-P), Iron-P (Fe-P), Occluded-P (Occ-P) and Calcium-P (Ca-P)] by modified P fractionation scheme of Peterson and Corey (1966). The procedure is depicted through the following flow chart (Fig.1). All the inorganic fractions except reductant soluble–P (occluded–P) were determined as per the ascorbic acid method. For determination of reductant soluble–P, 10 ml aliquot were taken in 125ml separatory funnels to which 10ml molybdate solution and 10ml isobutyl alcohol were added. The contents were shaken for 2min. After 5min of standing, the aqueous layer was discarded and the isobutyl alcohol mixture was washed by shaking it for 1min with 10ml 1*N* H_2SO_4. The aqueous layer was discarded and 10ml of ascorbic acid reagent was added (Page *et al.,* 1982), and the funnel was shaken for 1min. After discarding the aqueous layer, the blue coloured isobutyl alcohol layer was transferred to 25ml volumetric flask and the volume was made up to the mark with ethyl alcohol. The maximum colour intensity that developed in 10min was measured at a wavelength of 750nm.

Microbiological assay

Freshly collected soil samples were used for microbial biomass carbon, nitrogen and phosphorus (SMB-C, SMB-N and SMB-P) determination by the chloroform-fumigation-extraction method (Brookes and Joergensen 2006). For determination of SMB-C and SMB-N, 0.5 M K_2SO_4

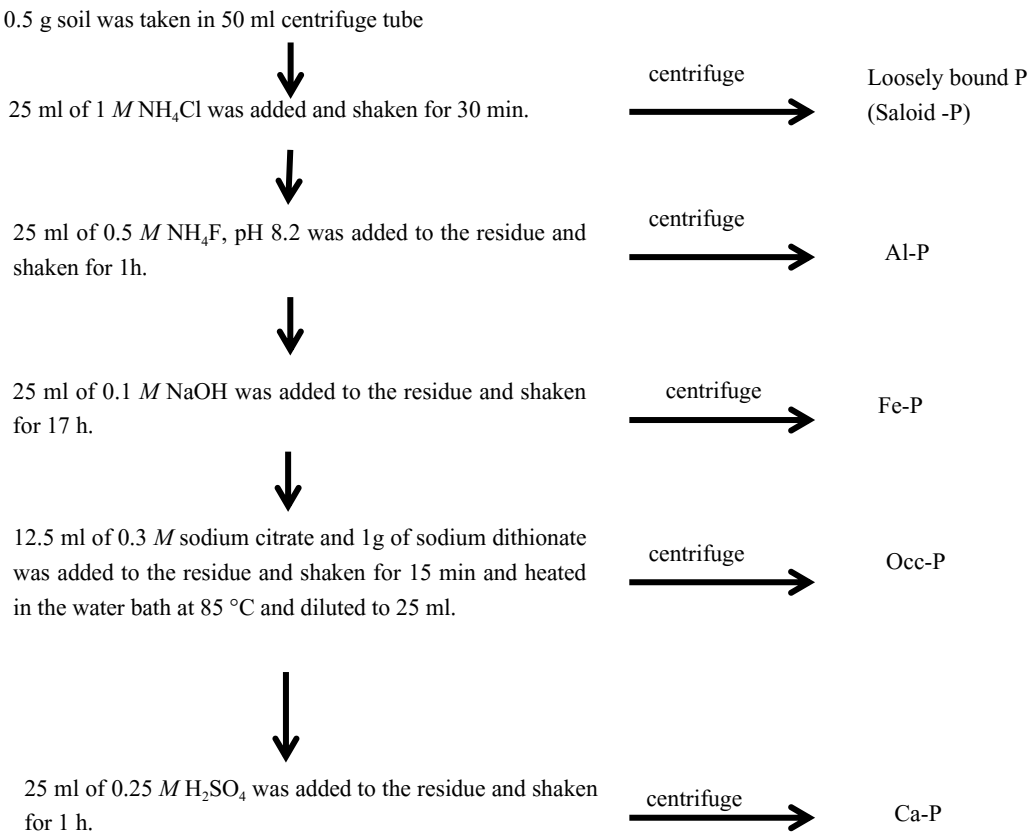


Figure1. Flow chart depicting procedure for fractionation of phosphorus

(1:2.5 ratio) is used as the extractant and determined by wet oxidation method for SMB-C and regular Kjeldahl method for SMB-N. In case of SMB-P, Olsen method is followed. The difference in C, N and P content between fumigated and non-fumigated sub-samples was determined and calculated using a conversion factor, K_{EC} = 0.25 (Jenkinson and Powlson 1976), K_{EN} = 0.45 (Jenkinson 1988) and K_{EP} = 0.40 (Brookes *et al*., 1982) for SMB-C, SMB-N and SMB-P respectively. BAS was measured in fresh soil samples by using standard base trap method in a NaOH solution (Pell *et al.,* 2006; Ohlinger *et al.,* 1996). Metabolic quotient (qCO_2) is derived by taking the ratio of BAS and SMB-C (Anderson and Domsch 1990). Dehydrogenase activity (DHA) was determined in air dried soil samples as per the method described by Klein *et al.* (1971). Intensity of reddish colour concentration of triphenyl formazan (µgTPF g^{-1}(dw) soil h^{-1}) was measured in spectrophotometer at a wavelength of 485nm. Phosphatase activity was determined in fresh soil samples as per the procedure described by Tabatabai and Bremner (1969). The alkaline phosphatase is determined with the MUB buffer of pH 11 and acid phosphatase with that of pH 6.5. Intensity of yellow colour (µg *p*-nitrophenol g^{-1}(dw) soil h^{-1}) was measured at 440 nm using a spectrophotometer.

Urease activity is determined by following the method described by Tabatabai and Bremner (1972).The ammonium released by the urease activity is measured after the soil is incubated with tris (hydroxyl-methyl) amino methane (THAM) buffer, urea solution and toluene at 37ºC for 2hr and ammonium release is determined by the steam distillation of the aliquot with MgO (Bremner and Keeney 1966). Fluorescein-diacetate (FDA) is determined by following the method described by Adam and Duncan, 2001. The fresh soil samples are incubated with potassium phosphate buffer and FDA solution at 25ºC for 30min and extracted with chloroform: methanol (2:1) and taken reading at 490nm in spectrophotometer.

Data analysis

Data generated from the laboratory analysis were subjected to the statistical analyses of variance appropriate to the experimental design. Data were assessed by Duncan's multiple range tests (Duncan 1955) with a probability $P \leq 0.05$. Least significant difference (LSD) between means was calculated using the SPSS program (SPSS version 16.0).

3. Results and Discussions

Response of the selected treatments *viz*. T_1: Control; T_2: Recommended dose of NPK fertilizers (100% NPK); T_3: Rice straw enriched RP compost@ 5t/ha; T_4: 50% NPK+ Rice straw enriched RP compost @ 5t/ha on SOC, mineral N and available K were presented in table 1.The SOC is found to be significantly different between the treatments and it is in the order of $T_4>T_3>T_2>T_1$ *($P\leq 0.05$)*. The available K and mineral N also showed the highest amount in the treatment T_4 though in the former there was no significant difference between the treatment T_2, T_3 and T_4. This suggest that the combine effect of enriched compost and inorganic fertilizer expressed the better management of nutrients in soil and the combination of the organic and inorganic fertilization can give the balance nutrition to the soil (Gaind *et al.,* 2006) maintaining the soil fertility and nutrient supplying capacity of the soil. Further compost not only slowly releases nutrients but also prevents the losses of chemical fertilizers through denitrification, volatilization and leaching by binding to nutrient elements and releasing it gradually with the passage of time (Arshad *et al.,* 2004). The total P, available P and sequential fractionation of P varies according to the organic and inorganic amendments in soil (Ajiboye *et al.,* 2002); the proportions of P applied and remove by crops, its fixation in soil and the climatic conditions (Schimidt *et al.,* 1996).

Table 1. Effect of enriched compost on available K, mineral N and SOC

Treatment	Avail K	NH_4	NO_3	SOC
	----------(kg ha^{-1})----------			(g kg^{-1})
T_1	250.6^{b}	89.48^{c}	11.29^{c}	3.16^{d}
T_2	302.3^{a}	94.50^{b}	22.58^{b}	4.95^{c}
T_3	286.1^{a}	93.24^{b}	21.74^{b}	5.58^{b}
T_4	293.4^{a}	104.12^{a}	27.60^{a}	6.84^{a}
CD ($P\leq 0.05$)	11.8	1.5	2.4	0.3

*Mean values followed by the same letter are not significantly different *($P\leq 0.05$)*

In our experiment also we observed the significantly *($P\leq 0.05$)* highest amount of total P in the treatment T_2 which is recommended dose of NPK fertilizers, followed by T_3 and T_4 (Table 2) treatments. Available P and sequential fractionation of P (like saloid-, Al-, Fe-, Occ- and Ca-P) were found to be highest in the treatment receiving integrated sources *i.e.* 50% NPK + enriched compost (T_4) and lowest in the control plot (T_1). The percent available P was found to be in the range of 1.93 to 2.96% and percent Ca-P from total P showed the highest

Table 2. Total and available P and sequential fractionation of P

Treatments	**Total P**	**Avail P**	**Saloid-P**	**Al-P**	**Fe-P**	**Occ-P**	**Ca-P**
		---------- **(mg kg^{-1})**----------					
T_1	600.4^{c}	11.5^{d}	15.3^{c}	12.4^{b}	21.3^{c}	9.1^{c}	184.2^{c}
T_2	672.7^{a}	15.7^{c}	22.9^{ab}	13.6^{ab}	24.3^{c}	12.9^{b}	193.4^{bc}
T_3	651.9^{b}	17.8^{b}	19.8^{b}	12.9^{ab}	32.5^{b}	14.4^{ab}	230.0^{ab}
T_4	650.3^{b}	19.4^{a}	24.7^{a}	14.4^{a}	39.6^{a}	15.3^{a}	255.0^{a}
CD ($P\leq 0.05$)	10.6	0.7	2.5	1.1	3.7	1.3	23.4

*Mean values followed by the same letter are not significantly different *($P\leq 0.05$)*

Table 3. Per cent of different fractions of P (% of total P)

Treatments	**Avail-P**	**Saloid-P**	**Al-P**	**Fe-P**	**Occ-P**	**Ca-P**
		----------**(mg kg^{-1})**----------				
T_1	1.93^{d}	2.55^{c}	2.07^{a}	3.55^{c}	1.52^{c}	30.8^{c}
T_2	2.34^{c}	3.40^{bc}	2.02^{a}	3.61^{c}	1.92^{b}	28.7^{bc}
T_3	2.71^{b}	3.01^{ab}	1.97^{a}	4.95^{b}	2.19^{ab}	35.0^{ab}
T_4	2.96^{a}	3.77^{a}	2.19^{a}	6.03^{a}	2.33^{a}	38.9^{a}
CD ($P\leq 0.05$)	0.1	0.4	NS	0.6	0.2	3.5

*Mean values followed by the same letter are not significantly different *($P\leq 0.05$).*

which range from 30.8 to 38.9% (Table 3). The percent labile P (saloid P) ranges from 2.55 to 3.77% and this fraction had a tendency to fluctuate and get replenished from other pools (Gikonyo *et al.,* 2008). Comparing among the different fraction Ca-P was found to be in higher quantity (184.2-255 mg kg^{-1}) than the other inorganic fractions of P, which is commonly observed under the long term inorganic and organic P trials (McKenzie *et al.,* 1992). The sequential fractionation of P depicts the variability and distribution of different P fractions to the crops (Hedley *et al.,* 1982) and the high content of Ca-P among the other fractions shows that it is acting as the buffer for available P in alkaline soil condition (Guo *et al.,* 2000).

Soil biochemical and microbiological properties were found to be very susceptible to the soil disturbance (Garcia *et al.,* 1999) as observed in conventional intensive cultivation systems. SMB-C, -N and -P content (Table 4) were recorded significantly less in treatment T_2 (recommended dose of NPK fertilizers) comparing to the other treatments and found to be higher in the treatment T_3 and T_4 as also reported by Leita *et al.* (1999). Estimation of microbial biomass gives the living biomass present in the soil and it represents the small amount from the total content of nutrients in the soil which rapidly turns over to supply inorganic portion of nutrients to crops (Tate 1984). It also acts as the indicator of soil disturbance in different management practices (Brookes 1995).The increase in microbial biomass in these treatments shows that it is stimulated in enriched soils (Jenkinson and Ladd 1981). Analysis of these indicators directly or indirectly determines the active nutrient status of the soil, mobilization and availability to the crops finally determining the quality of the soil.

Enzyme urease activity (Table 5) increases as N content in the different treatment soils increases showing the direct correlation (Makoi and Ndakidemi 2008).

Table 4. Microbial biomass carbon, nitrogen and phosphorus on different soil amendments

Treatment	SMB-C	SMB-N	SMB-P
	----------(µg g^{-1})----------		
T_1	135.1^{c}	24.7^{b}	2.7^{c}
T_2	161.8^{b}	49.3^{ab}	3.4^{bc}
T_3	205.7^{a}	57.4^{ab}	3.9^{b}
T_4	220.6^{a}	69.0^{a}	5.0^{a}
CD (P≤0.05)	14.8	22.0	0.4

*Mean values followed by the same letter are not significantly different (P≤0.05)

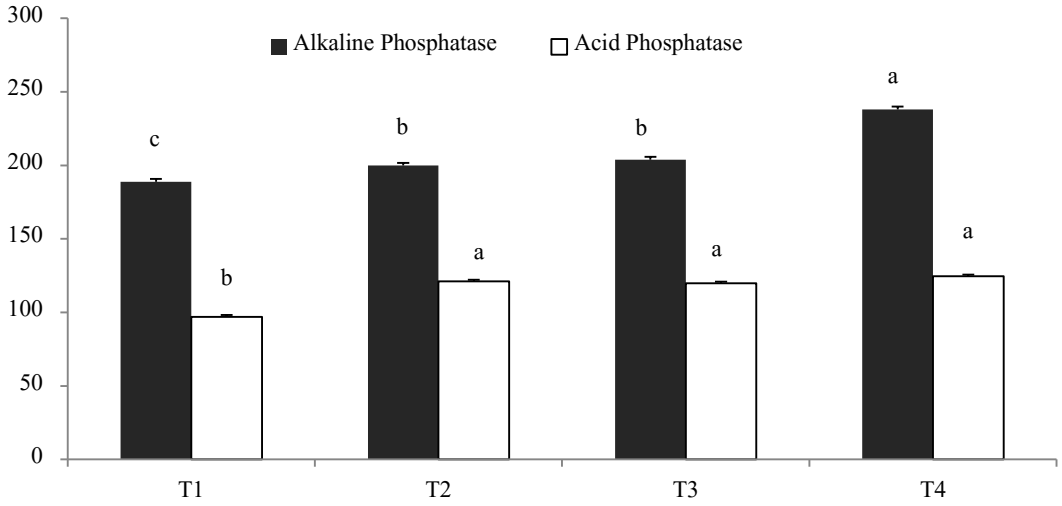
Soil enzymes are known for its importance in cycling of nutrients in nature (Nannipieri *et al.,* 2002; Yao *et al.,* 2006) and they are nutrient specific which catalyzed the hydrolysis reactions. The enzymes *viz*. dehydrogenase and FDA are considered as an indicator of the total microbial activity and act as the catalyst in the turnover of carbon (Smith and Pugh 1979; Schnurer and Rosswall 1982).The use of different amendments promoted a significant increase in FDA and dehydrogenase activity compared to control (Table 5). Alkaline phosphatase (Fig. 2) was found to be significantly higher *(P≤0.05)* in the treatment T_4 and the lowest in T_1. But acid phosphatase failed to show the significant effect between the treatments. The alkaline phosphatase activity was recorded higher than the acid phosphatase in all the treatments under study. In many studies phosphatase activity is found to decrease as the content of P increases in the soil but in this study it was observed that the phosphatase activity increased. This might be due to the ability to mobilized soil mineral elements is higher in plots receiving higher quantity of organic C, as the activity of these enzymes was found to associate with organic matter content of the soil (Jordan and Kremer 1994).

Table 5. Enzymes dehydrogenase, fluorescent diacetate, urease and basal respiration in different treatments

Treatment	Dehydrogenase	FDA	Urease	BAS
	µg TPF g^{-1}DW soil h^{-1}	µg fluorescent g^{-1} DWsoil h^{-1}	µg NH_4 released g^{-1} soil hr^{-1}	µgCO_2 g^{-1}DW h^{-1}
T1	8.12^{b}	1.68^{d}	28.0^{c}	0.18^{b}
T2	9.01^{ab}	1.85^{c}	32.7^{bc}	0.88^{a}
T3	9.40^{ab}	1.96^{b}	42.0^{b}	0.86^{a}
T4	9.53^{a}	2.04^{a}	60.7^{a}	0.93^{a}
CD (P≤0.05)	0.8	0.05	6.6	0.06

*Mean values followed by the same letter are not significantly different *(P≤ 0.05)*

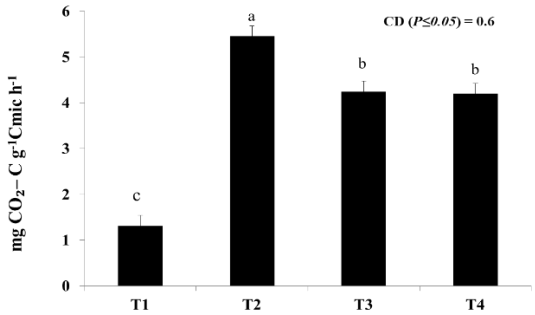
Figure. 2. Alkaline and acid phosphatase (µg *p*-nitrophenol g^{-1}DW soil h^{-1}) as influence by different soil amendments



* The same letters above bars are not significantly different according to Duncan's test (P≤0.05) between different treatments. Alkaline phosphatase CD (*P≤0.05)* = 6.4 and acid phosphatase CD (*P≤0.05)* = 1.6.

The BAS was found to be insignificant between the treatments T_2, T_3 and T_4 but significantly lower basal respiration was found in control plot (Table 5). The Fig. 3 showed the significantly highest qCO_2 in the treatment T_2 where 100% recommended doses of NPK was applied and the lowest amount was observed in the control plot. The treatment T_3 and T_4 was lower than the treatment T_2 but failed to show the significant effect. The metabolic quotient (qCO_2) is affected by the inorganic fertilized (T_2) soil by showing significantly higher amount compared to the other treatments which indicates that the stress is more in chemical fertilized soil as the imbalance nutrient and disturbance in soil has negative effect on the efficiency of microbial activities and show high qCO_2 (Anderson and Domsch 1990; Nannipieri *et al.,* 1997).

Figure 3. Metabolic quotient (mg CO_2-Cg^{-1} Cmic h^{-1}) in soil amended with enriched compost and mineral fertilization in a 3-years old wheat green gram crop rotation.



*The same letters above bars are not significantly different according to Duncan's test (P≤0.05) between different treatments.

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