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Phosphorous and Mung Bean Residue Incorporation Improve Soil Fertility and Crop Productivity in Sorghum and Mungbean-Lentil Cropping System

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ABSTRACT

In sorghum and mungbean – lentil cropping system, field experiments were conducted for three successive years to assess the effect of mung bean residue incorporation on sorghum and succeeding lentil productivity along with different doses of phosphorus (P; 0, 30, 60 kg ha^{-1}) applied to these crops. The level of soil fertility was also tested with or without incorporation of mung bean residue. The interaction of phosphorus to mungbean residue incorporation was thus studied in relation to improve crop productivity with balancing fertilizer requirements through an eco-friendly approach. Sorghum grain yield increased significantly when 60 kg P_2O_5 ha^{-1} was applied and mungbean residue incorporated. The response was reduced to 30 kg P_2O_5 ha^{-1} when mungbean residue was not incorporated. The succeeding lentil crop responded up to 60 kg P_2O_5 ha^{-1} only when preceding sorghum crop received 0 or 30 kg P_2O_5 ha^{-1}. Response to applied P_2O_5 to lentil reduced to 30 kg ha^{-1} when preceding sorghum crop received 60 kg P_2O_5 ha^{-1} and mungbean residue incorporated. Available soil nitrogen, phosphorus, and organic carbon content increased when mungbean residue was incorporated; however, available potassium (K) of the soil decreased from its initial value.

Keywords: grain yield, mungbean residue incorporation phosphorus, phosphorus, potassium, organic carbon content, soil nitrogen, sorghum – lentil cropping system

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INTRODUCTION

Sorghum (*Sorghum bicolor* L.) is an important kharif (summer) crop widely grown in different parts of world. In India, sorghum occupies about 1.1 million hectares area mainly under rainfed conditions representing 30% of the world acreage. With the development of short duration improved varieties double cropping is possible. Sorghum is generally grown in intercropping systems due to several benefits of this system (Francis et al., 1976; Ofori and Stern, 1987). Among intercrops, the legumes, like mungbean, cowpea, and soybean, are the preferred crop (Singh and Ahlawat, 2005). After harvest of the sorghum, the field is often rotated with a legume (Ali et al., 1991; Rathore, 2000). Most of the soils in semi arid tropical regions (SAT) are low in fertility and organic carbon and maintenance of organic carbon (C) in cropping systems in this region is a very difficult task. To maintain soil productivity it is needed to replenish organic manures and consequently for sustainable yields, it is essential to add a lot of organic matter along with chemical fertilizers to the soil (Rabindra et al., 1985). Mungbean (*Vigna radiata*) being a legume, plays a vital role in the maintenance of soil fertility because of its nitrogen (N) fixation and narrow C: N ratio in crop residue (Anonymous, 1990). The residue could be best utilized for recycling into the soil for its fertility maintenance. In addition to the organic manures, phosphorus (P) also plays an important role in legume based cropping systems because of its role in root development and greater atmospheric nitrogen fixation (Flank, 1998). Among major nutrients used in crop production, the use efficiency of P is minimum. Management of phosphorus is, therefore, imperative in continuous cropping systems because of its fixation in soil. Since the information on the effect of integration of P and legume residue in sorghum + mungbean – lentil-cropping system is lacking, the present study was conducted.

MATERIALS AND METHODS

Experimental Design and Treatments

The field experiment was conducted for continuous three years in the field of research farm of Indian Institute of Pulses Research, Kanpur (26° 3′ N, 80° 15′ E) during the crop season starting every year from the month of June and extending to April next year. The experiment was initiated in July 2000 and terminated in April 2003. Experimental treatments comprised of 6 main plots in kharif season (combinations of three doses of P to sorghum viz, 0, 30, and 60 kg ha^{-1}, represented by S_0, S_{30}, and S_{60}, respectively, and two levels of mungbean residue viz., without incorporation (M_0) and with incorporation (M_1), making six treatment combinations (denoted by S_0M_0, S_0M_1, $S_{30}M_0$, $S_{30}M_1$, $S_{60}M_0$, and $S_{60}M_1$) and in sub plots three doses of phosphorus to lentil viz., 0, 30, and 60 kg ha^{-1}

(denoted by L_0, L_{30}, and L_{60}) in rabi season (November to April). The experiment was laid out in split plot design with four replications. In the first year of trials, all of the 6 main plots in the kharif season did not receive any mungbean residue incorporation; therefore, with or without residue incorporation treatments remained the same. Sorghum variety *varsa* and mungbean variety *PDM11* were grown in 1 : 3 row proportions during kharif season (June to October) in an intercropping system. The main plot size was 7.05 × 10 meters and the sub plot size was 7.05 × 5 meters. After picking of pods in September and harvesting of sorghum in October, every year the mungbean was chopped in 1-inch length pieces and the residue was spread uniformly in plots as per treatments. Residue incorporation was done manually through spade in the top 15-cm soil depths. Immediately after residue incorporation, all plots were irrigated with 5 cm depth of water, which also acted as pre-sowing irrigation. In plots without residue incorporation, the entire amount of mungbean residue was removed. Similarly, sorghum residue was removed from every plot. In mungbean residue incorporation treatments, residue obtained from each plot was incorporated at 18 q ha^{-1} on dry weight basis. While for treatments without residue incorporation, the entire crop residue was removed.

Plant Culture

The details of sowing, harvesting, and residue incorporation treatments are given in Table 1. Row and plant spacing was 30 × 10 cm and 45 × 15 cm for mungbean and sorghum, respectively, throughout the period of the experiment. On the other hand, lentil was sown at a 30 × 5 cm distance. The experiment was conducted continuously for three years at the same site and with the same randomization.

Table 1
Date of sowing and harvesting of crops and time of residue incorporation

Particular	2000–01	2001–02	2002–03
Sowing of sorghum and mungbean	June 28, 2000	July 3, 2001	21 June, 2002
Final picking of pod of mungbean	september 15, 2000	September 12, 2001	September 10, 2002
Harvesting of sorghum	October 23, 2000	October 20, 2001	October 20, 2002
Incorporation of mung residue	October 28, 2000	October 23, 2001	October 22, 2002
Sowing of lentil	November 12, 2000	November 8, 2001	November 6, 2002
Harvesting of lentil	April 1–2, 2001	March 30, 2002	March 26, 2003

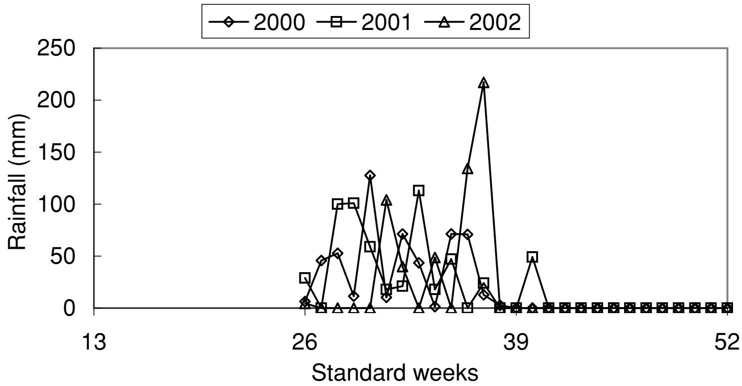

Figure 1. Rainfall pattern for three sucessive years at experimental sites.

The sorghum + mungbean crops were raised rainfed as monsoon is sufficient with annual rainfall of 805 mm in this area for its normal cultivation. Rabi crop (lentil) was provided one 5 cm depth irrigation at 60 days after sowing. Weeds were removed manually in both the seasons and infestation of shoot borer in sorghum crop was controlled by an application of phorate every year. The yearly rainfall amounts during the rainy season (last week of June to September) is given in Fig. 1.

Mineral Nutrition

The soil of the experimental field is Typic Ustochrept (Inceptisols) with a silty clay loam texture, pH 7.3, low in organic carbon (0.241%) and nitrogen (181 kg ha^{-1}), medium in available P (14.8 kg ha^{-1}), and potassium (K) (216 kg ha^{-1}). Except P, the nitrogen was applied to each crop as per recommended dose. Seeds and fertilizer were calculated based on the area occupied by the crop under intercropping system. Fertilizers were broadcasted manually and mixed well in top 15 cm of the soil. The following nutrient elements were applied to crops such as 60 kg N and P as per treatments in sorghum, 18 kg N and 46 kg P_2O_5 ha^{-1} to mungbean, and 23.5 kg N, 20 kg K_2O ha^{-1} and P as per treatment to lentil each year. The mungbean residue incorporated contained an average N, P, and K content of 1.32%, 0.33%, and 1.78%, respectively. Therefore, through residue incorporation soil received about 20 kg N, 2.2 kg P, and 32 kg K ha^{-1} year^{-1}. The source of fertilizer was urea and diammonium phosphate and muriate of potash. Before sowing of the crop in first year and also after completion of three years crop cycle, the soil samples were collected from top 0–15 cm depth and were analyzed for N, P, K, and organic carbon content.

Soil Analysis

Before sowing of first crop in 2000 and after the harvesting of lentil in 2003, soil samples (0–15 cm) were collected from each plot (by combing 8 samples from each sub plots). The samples were air-dried and crushed to pass a 2 mm sieve before chemical analysis. Organic carbon was determined using a modified Walkley – Black procedure utilizing dipotassium chromate ($K_2Cr_2O_7$) and sulfuric acid (H_2SO_4) as described by (Sefrioui et al., 1970); pH was determined by extraction with a glass electrode in a soil: water ratio of 1:2 m potassium permangate ($KMnO_4$), mineralizable nitrogen was estimated by an alkaline permangate method (Aubbiah and Asija, 1956); phosphorus was extracted with sodium bicarbonate (Olsen et al., 1954) and potassium by (Hanway and Heidel, 1952).

Statistical Analysis

The results were analyzed using the SPSS package version 11. Interaction effects were found significant in lentil, sorghum yield, and phosphorus uptake in third year.

RESULTS AND DISCUSSION

Grain Yield of Kharif Crops

Data presented in Table 1 revealed that there was a continuous decline in grain yield in the S_0M_0 treatment over the years. This decline was more in mung bean residue removal than the residue incorporation treatment. In the year 2000 application of 30 and 60 kg phosphorus ha^{-1} proved beneficial in increasing the sorghum yield over control. But no significant difference was observed between 30 and 60 kg ha^{-1} of applied phosphorus. In second year too, higher doses of applied P (60 kg ha^{-1}) yielded significantly more than 30 kg ha^{-1} P and control. But with the mungbean residue, incorporation of 30 kg ha^{-1} P gave an at par yield over the 60 kg ha^{-1} P. Mungbean residue incorporation treatments yielded higher as compared to the treatment where the residue removed and only 30 kg of P were applied. In the third year, the interaction effect of mungbean residue incorporation and phosphorus applied to sorghum crop was found significant (Fig. 2). Highest sorghum yield (1668 kg ha^{-1}) was obtained when sorghum received 60 kg ha^{-1} P and mungbean residue incorporated against a yield of 1095 kg ha^{-1} in residue removal treatment. Response of sorghum to P depends mainly on the moisture status in the soil, which was limiting during the first year (Fig. 1) as very little rainfall received after 15 September (15 mm) while in second year it was comparatively better (73 mm) and it was much better in

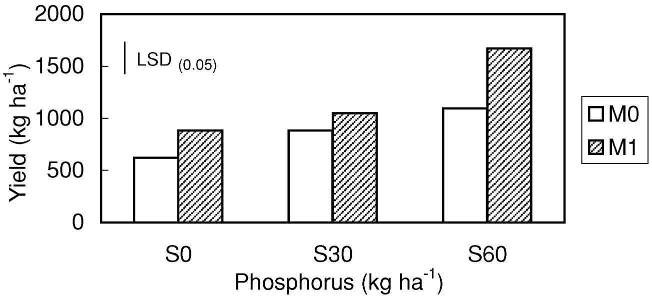

Figure 2. Interaction effect of mungbean residue and phosphorus on sorghum grain yield.

third year (217 mm). Advantages of mungbean incorporation could be mainly due to the positive effects of crop residue on soil fertility as reported by others (Bhandari et al., 1992; Singh and Swarnalakshmi, 2005). Response of sorghum to 60 kg ha^{-1} in third year in residue incorporation treatment may be due to interactive effects of P at higher level of N at better moisture level. The available soil N status has been increased due to addition of mungbean residue (Table 4). Response of sorghum to P application varies from 30 to 60 kg ha^{-1} depending upon the moisture and N conditions of the soil (Rathore, 2000; Singh et al., 1993; Tripathi and Suraj Bhan, 1995). If a good rain received it responded to higher doses of P in presence of higher soil N. Mungbean yield was not affected in any of the year due to different treatments applied in kharif and rabi crops. It is obvious because mungbean crop was raised at optimum fertility levels.

Yield of Lentil Crop

Perusal of the results given in Table 3 revealed that in 2000–01 lentil yield was not affected by any of the treatment applied in kharif crop. But directly applied P_2O_5 at 30 kg ha^{-1} to lentil crop in rabi season was found to increase the yield by a margin of 31.86% over control and no further significant improvement in grain yield was found due to application of 60 kg ha^{-1} P_2O_5. In 2001–02, P applied to sorghum crop significantly affected yield of lentil. Significantly higher lentil yield was obtained in $S_{60}M_1$ treatment over rest of the five treatments. The increase was 20.87% over control. Direct applied phosphorus to lentil crops had a response of only up to 30 kg ha^{-1} in the second year too. In third year, interaction effect between kharif treatments and P applied to lentil crop was found significant (Fig. 3). Irrespective of the kharif-applied treatments, significantly higher lentil yield was obtained in L_{60} over L_0. But this increase in yield was narrowed down with the increasing doses of kharif applied P. The L_{60} proved superior only when no P was applied in kharif crop. But response

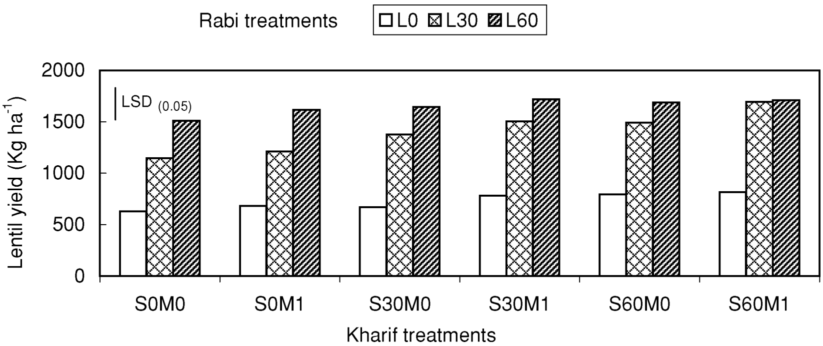

Figure 3. Combined effect of kharif and rabi treatments on grain yield of lentil.

to applied P reduced to L_{30} with $S_{60}M_1$ treatment. Response of applied P could be due to medium P status of the soil (Singh et al., 2005; Tandon, 1987). Since sorghum is a heavy feeder of plant nutrients, it is obvious that in no P treatments the available soil P status was decreased (Fig. 4) hence succeeding lentil crop responded at higher doses of applied P.

Available Nitrogen

Significant difference in N status of the soil was observed due to different kharif treatments (Table 4). All the treatments receiving residue incorporation resulted higher available N than the initial soil N. Among all the 6 treatments applied in kharif season S_0M_1 treatment was significantly superior over rest of

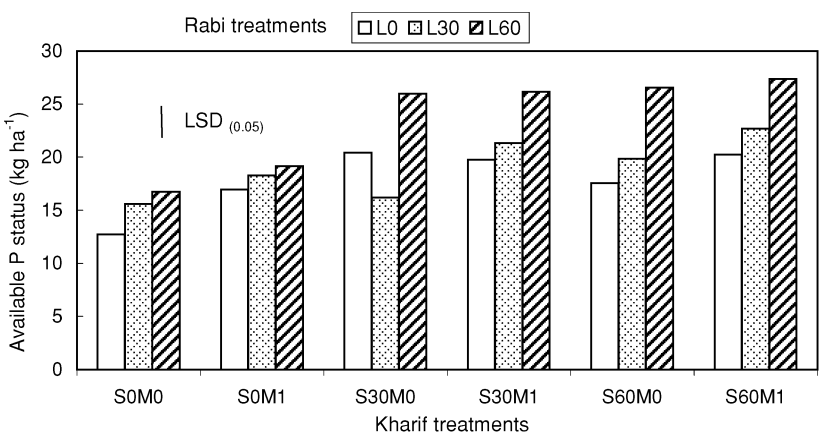

Figure 4. Interaction of kharif and rabi treatments on available P status of the soil.

Table 2
Yield of kharif crops due to different treatments

	Sorghum kg ha^{-1}		Mungbean kg ha^{-1}		
Treatments	2000	2001	2000	2001	2002
Kharif					
P_0 M_0	982	831	430	463	575
P_0 M_1	988	908	439	456	549
P_{30} M_0	1194	951	466	466	556
P_{30} M_1	1181	1109	457	476	543
P_{60} M_0	1246	1098	466	453	548
P_{60} M_1	1262	1125	455	456	541
C.D.($p = 0.05$)	122	116	N.S.	N.S.	N.S.
Rabi					
L_0	1140	1012	454	463	558
L_{30}	1151	999	449	458	553
L_{60}	1135	1000	453	464	545
C.D.($P = 0.05$)	N.S.	N.S.	N.S.	N.S.	N.S.

the treatments. Variable phosphorus doses to lentil also leave higher available soil N than its initial value but they were statistically at par among themselves. Higher build up of available soil N in all the treatments may be because of the direct addition of N to the crops in the systems through fertilizer N or crop residue and also because of inclusion of pulses in the cropping system which might have build up nitrogen through atmospheric N fixation as reported by others (Antil et al.,1989; Peoples et al., 1995; Singh and Ganeshamurthy, 2004). Higher build up in S_0M_0 treatments may be due to lower crop yield (Tables 2 and 3 and Figs. 2 and 3) and consequently lower uptake of N.

Available Phosphorus

All treatments applied in kharif season have increased the soil P status (Fig. 4). But the degree of increase varied having lowest (0.21 kg ha^{-1}) in S_0M_0 treatment and highest (8.62 kg ha^{-1}) in $S_{60}M_1$ treatment. Similarly the available P status was increased by a margin of 59.79% when lentil continuously received 60 kg P_2O_5 ha^{-1} over control. There was an increase in available P status of the soil even in plots, which did not receive any P in rabi lentil crop by a margin of 21.21% from the initial soil P status (14.8 kg ha^{-1}). Variable degree of available soil P accumulation is mainly due to the different rates of fertilizer P applied either directly through addition of P fertilizer or indirectly through inclusion of crop residue. The tendency of P accumulation in soil in intensive cropping systems due to its continuous application or addition of crop residue has been

Table 3
Yield of lentil as influenced by different treatments

Treatments	Lentil yield kg ha^{-1}	
Main plots	2000–01	2001–02
P_0 M_0	1065	1207
P_0 M_1	1141	1299
P_{30} M_0	1045	1230
P_{30} M_1	1285	1330
P_{60} M_0	1292	1279
P_{60} M_1	1192	1459
C.D.(p = 0.05)	N.S.	156
Sub plots		
L_0	976	1160
L_{30}	1249	1362
L_{60}	1287	1379
C.D.(P = 0.05)	127	111

observed by several workers in different cropping system (Badanur et al., 1990; Maskina et al., 1988; Sharma and Mitra, 1991; Sharma et al., 1987; Singh et al., 2005).

Available Potassium

All the treatments applied in kharif and rabi season considerably reduced the soil K status of the soil from its initial value (Table 4). But effects were dissimilar due to rabi and kharif treatments. In kharif, irrespective of the P applied to sorghum crop, plots receiving residue incorporation showed higher level of available K than residue removal. But significant difference was observed only up to 30 kg of applied P to sorghum only. Although there was a consistent decrease in K status of the soil due to increasing doses of P to lentil, but the difference was not significant. Reduction of available K in all treatments over its initial value is mainly its lower addition in comparison to the plant removals. A pulse crop like mungbean and lentil removes about 90 and 36 kg K ha^{-1}, respectively (Ganeshamurthy et al., 2004). While in case of sorghum it varies to 100–130 kg K_2O ha^{-1} (Rathore, 2000). Pulses may remove sizeable quantities of K, and in the case of no addition of K to the soil, the non exchangeable K becomes a major source for potassium requirement of pulse crops in India (Ali and Srinivasarao, 2001). As in this experiment, fertilizer K was added to only lentil crop a reduction in available K of the soil was obvious. Lower reduction in available K of the soil in residue incorporation treatments may be attributed to the direct addition of potassium to the soil through decomposition and probably

Table 4
Effect of different kharif and rabi treatments on soil fertility

Treatments	Soil fertility parameters		
Kharif	O.C. (%)	N (kg ha^{-1})	K (kg ha^{-1})
S_0 M_0	0.224	214.00	168.33
S_0 M_1	0.256	268.66	185.66
S_{30} M_0	0.250	219.66	162.66
S_{30} M_1	0.263	258.33	184.33
S_{60} M_0	0.264	207.66	166.00
S_{60} M_1	0.274	250.33	177.33
C.D.(p = 0.05)	0.018	17.99	13.10
Rabi			
L_0	0.251	237.16	181.16
L_{30}	0.256	232.16	172.83
L_{60}	0.257	235.00	168.16
C.D.(P = 0.05)	N.S.	N.S.	N.S

may cause reduction of fixation and release of K due to the interaction of organic matter with clay.

Organic Carbon Content

Soil organic carbon content depicted in Table 4 showed a large variation due to different treatments. All the treatments applied in kharif crops increased the carbon content of the soil significantly with varying extent over S_0M_0. But highest increase of 22.32% and 13.69% respectively over S_0M_0 and initial value (0.241%) was reported in $S_{60}M_1$ treatment. None of the treatments except S_0M_0 showed a decrease in organic carbon content from its initial value. Phosphorus applied to rabi lentil crop also increased the soil carbon content to the level of 0.251, 0.256, and 0.257%, respectively, in L_0, L_{30}, and L_{60} treatment, over its initial value of 0.241%. Increase in carbon content of the soil due to P application and legume residue incorporation was in conformity with the others (Ahlawat et al., 1977; Rixon, 1966). Increase in carbon content of the soil due to increasing doses of P to lentil may be the better root growth at higher level of P and higher leaf drops in lentil crop (Singh and Ganeshamurthy, 2004; Singh et al., 2005) besides other benefits of legumes, which might have served as a source of soil organic carbon. The decrease in organic carbon in S_0M_0 over its initial values may be lower biomass addition. Decrease in soil organic content in control plots has been reported by others (Sharma, 1998; Singh et al., 1998).

CONCLUSION

Mungbean crop residue may be applied as a possible supplemental source of nutrients in the production of sorghum and lentil and improvement of soil fertility. The incorporation of crop residue is a safe eco-friendly practice without any adverse effect on crop yield. Further, this study suggests that continuous applications of P in this system may cause significant buildup of soil P status. But addition of 20 kg K_2O to lentil is not adequate to meet the requirements of K to all crops and to maintain the soil K status. Thus, there is a need to increase the K application in this cropping system to sustain the soil productivity. Lentil responded only 30 kg of applied P when preceding sorghum crop received 60 kg P_2O_5 and mungbean residue was incorporated. Response to applied P could be increased with mungbean residue incorporation.

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