REHABILITATION OF PROBLEM SOILS THROUGH ENVIRONMENTAL FRIENDLY TECHNOLOGIES: ROLE OF SESBANIA AND PHOSPHORUS

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Abstract

The effect of sesbania and phosphorus application (0,15,30,60 and 90 kg P/ha) on rice field under sodic soil conditions was investigated. Results revealed that green manuring and P application significantly increased the productive tillers and paddy and straw yield. Maximum paddy yield was recorded with the application of 90 kg P/ha. Significant differences among the treatments were observed. P requirement of rice for realizing near maximum yield (95 percent of maximum) was 57.5 kg P/ha with sesbania and 64.5 kg P/ha without sesbania. Agronomic efficiency and P recovery by rice were significantly greater with green manuring as compared to no green manuring. Agronomic P efficiency was significantly greater at the lowest level of P application. Phosphorus recovery by rice ranged from 10.17 to 20.59 % with a mean of 15.4 %. The highest percent recovery of P fertilizer was the recorded at the lowest rate (15 kg P/ha) of P application.

Key words: lowland rice, N uptake, P requirement, salinity, agronomic efficiency

INTRODUCTION

Salinity is one of the major soil problems causing low crop yields and economic returns in Pakistan. The total area affected by salinity based on soil survey reports is 5.9 million hectares (Rafiq, 1990), whereas the calculations by Khan (1993) show it to be 6.3 million ha.

Rice occupies a significant position in the agricultural economy of Pakistan. Besides being the number two food staple of the population, it has emerged as a major export commodity, contributing more than 15 percent of the national foreign exchange earnings (Zia, 1990). Despite the prime position of rice in the economy of the country, yields are discouragingly low: only 2.7 and 1.6 t/ha for IR-6 and Basmati varieties respectively. However, yield potentials of medium coarse and fine Basmati varieties at experimental stations reach as high as 8 t/ha for IR-6 and 4 t/ha for Basmati (Zia, 1990). Thus a substantial gap exists between potential rice yields and current production realized by the farmers.

Rice is grown under lowland reduced (removal of oxygen due to flooding) conditions in Pakistan. Rice soils of Pakistan are generally saline-sodic with varying degrees of calcareousness (Zia, 1990). Salinity affects the growth of rice differently and vary depending on the stage of plant development (Maas and Hoffman, 1977). Sodicity reduces yields as a result of deficiencies in micronutrients like Fe, Cu, and Zn as well as in macronutrients like Ca and P, in addition to the direct effects of higher pH. Almost all soils in Pakistan are low in organic matter and hence poor in fertility. About 80-90 percent of the soils are low to medium in P concentration, and most soils are alkaline and calcareous in nature affecting P availability (Zia, 1990). Because of high soil pH, saline-sodic soils have low availability of P and micronutrients. It is well established that plants can help in the release of plant nutrients by lowering the soil pH (Nagarajah et al., 1989; Sharma, et al. 2001). Sesbania *(Sesbania aculeata)* used as green manure improves soil productivity by adding organic matter and increasing biological nitrogen fixing . It can also reduce the sodicity problem (Zia et al., 1992, Johnkutty, et al. 2000, Chauhan, et al. 2001).

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Description of the Study Area

Field investigations were performed at the Saline Agriculture Research Station, Sadhuke, Punjab, Pakistan, 30 kilometers north of Lahore. It is located at

74^0 18' E longitude and 31^0 35' N latitude in the northeastern portion of the Indus plain. This plain extends from the Potwar Plateau southward about a thousand kilometers to the Arabian sea. The Indus plain was formed from alluvium deposited by rivers into an ancient shallow sea. Salts have accumulated in soils from both salty ground water and from a canal irrigation system developed in the late eighteenth and early nineteenth centuries. With no drainage outlet, salt accumulation in soils resulted.

The study area has an arid and continental climate with very high summer temperatures (35-40 ^{0}C) and mean annual rainfall (325-750mm). In early summer, before the start of the monsoon season, potential evaporation is several fold larger than precipitation (Khan, 1993).

The soil at the study site is a fine-loamy, mixed, thermic Typic Natrustalf. Physico-chemical analysis of soil from the experimental site is shown in Table 1. The soil is alkaline, calcareous and saline-sodic in nature. It is deficient in N and organic matter, however, potassium and other micronutrents are adequate

MATERIAL AND METHODS

The experiment was performed in a randomized block design with three replications. Sesbania aculeata as green manure was sown in the first week of May. Different rates of P (0, 15, 30, 60, and 90 kg/ha) were applied and sesbania was grown. These rates were also applied to another piece of land where no sesbania was grown. Sesbania was grown for 60 days and then was incorporated into the soil with a rotavator 5 to 6 days before transplanting rice. The field was flooded and puddled before rice (Basmati-385) was transplanted. Nitrogen and potassium fertilizers at the rate of 80 and 50 kg/ha were applied at the time of transplanting. Two thirds of the N and all of the K were applied as basal doses before sesbania was planted. The remaining 1/3 N was applied at the time of panicle initiation. The rice crop was grown to maturity. Data on productive tillers and paddy and straw yields were recorded at the time of harvest. Plants were chemically analyzed for N and P following procedures described by Prevel et al. (1987). N and P uptake in straw and grain were determined by multiplying the concentration of the element by its respective yield. Agronomic efficiency and P recovery were also calculated using formulas of Mengel, Kirkby (1987).

The experimental data for all the plant parameters were analyzed statistically, through analysis of variance based on a randomized complete block design using an SAS Program. The effects of treatment means were compared by applying Duncan's Multiple Range Test (Duncan, 1955). All treatment comparisons were made using an alpha level of 0.05 significance.

RESULTS AND DISCUSSION

Effect of Sesbania and Phosphorus Application on Rice Yield

Results of the study revealed, that green manuring significantly increased number of productive tillers and paddy and straw yields (Table 2). Continued supply of N from the sesbania application probably resulted in a higher number of productive tillers until the reproductive stages of rice were reached**.**

Phosphorus application also increased the number of productive tillers and paddy and straw yields (Table 2). Maximum productive tillers were recorded with the application of 90 kg P/ha; differences due to all levels of P application were significant. These significant increases in grain production indicate the role of P in seed formation as reported by Brady (1999). Differences in paddy yield due to all rates of P application compared to control were significant..

Effect of Sesbania and Phosphorus Application on Phosphorus Concentration

Phosphorus concentrations in rice grain and straw significantly increased with the increasing rates of P application except for differences between 30 and 60 kg P/ha treatments. Differences in P concentration in grain and straw due to green manuring were also significant. The maximum concentration was recorded with the application of 90 kg P/ha, followed successively by lower application rates to the control (Table 3). In flooded rice, the concentration of water soluble and available P increases with lowering the redox potential (Eh) of the flooded soil and the decreasing pH of calcareous saline-sodic soil.

Effect of Sesbania and Phosphorus on Phosphorus Uptake in Rice

Phosphorus uptake in rice grain, straw and grain+straw (total) was significantly increased because of sesbania green manuring (Table 4). Phosphorus uptake, however, has been reported by Zia, (1992) to have a negative correlation with pH. The ideal range for maximum P availability to plants lies between pH 6.0-7.0 (Brady, 1999).

The alkaline and calcareous soil conditions resulted in significant P uptake in this study. The data are in agreement with Swarup (1987). He reported that green manuring application caused increased utilization of phosphorus by the crop not only from the added fertilizer but also from the reserve supplies of soil P. Sesbania green manuring increases availability of P through the mechanisms of reduction, chelation and favorable changes in soil pH occurring in flooded rice soils. Probably these factors created favorable conditions for rice growth and enhanced P uptake in this study.

Phosphorus uptake was increased significantly with the application of phosphorus at each rate of application (Table 4). Phosphorus application increased the availability of P in the soil solution, yielding significant differences among the treatments under study.

Determining Phosphorus Rate for obtaining Maximum Yield

Phosphorous required for realizing near maximum paddy yield was determined as 57.5 kg P/ha under green manuring and 64.5 kg P/ha for no green manuring treatment. On the average 60 kg P/ha was required for obtaining near maximum yield under all conditions.

Effect of Sesbania and Phosphorus Rates on Agronomic Efficiency and P Recovery

Agronomic efficiency and P recovery by rice were significantly improved with sesbania green manuring (Table 5). Agronomic P efficiency was significantly greater at the lowest level of P application. Phosphorus recovery by rice ranged from 10.17 to 20.59 % when calculated by the formulas given by Mengel and Kirkby (1987), with a mean of 15.4 %. Recovery was the highest at the lowest rate (15 kg P/ha) of P application. There was no significant difference in recovery due to 15 and 30 kg P/ha; the highest P rate resulted in the lowest P recovery (Table 5).

According to Brady (1999) maximum P availability to plants is obtained when the soil pH is in the range of 6-7. Even in this range, however, it should be emphasized that phosphate availability may still be very low and the added soluble phosphates are fixed by soils. The low recovery (perhaps 10-30 percent) by plants of added P is partially due to this fixation. Low P recovery in this study might be the result of higher P fixation capacity of the soil

CONCLUSIONS AND RECOMMENDATIONS

The study revealed that sesbania green manuring and P application significantly increased the productive tillers and paddy and straw yields.

1. Phosphorus requirement under sesbania treatment to realize near maximum yield (95 % of maximum) was estimated as 57.5 kg P/ha and without green manuring 64.5 kg P/ha. It indicates that sesbania green manuring accumulated P in the soil or helped in the enhanced uptake from unavailable fractions.

2. Agronomic P efficiency and P recovery by rice were significantly greater with green manuring, another beneficial effect of sesbania.

3. Increased application rates of P were of no use as agronomic P efficiency was significantly greater at the lowest level of P application. Moreover, maximum P recovery was achieved by the lowest rate (15 kg P/ha) of application. It indicates that low rates of P can meet the nutritional needs of rice. One of the hypotheses of this study was that P application could alleviate harmful effects of sodicity. This proved to be wrong but sesbania green manuring was a sustainable effective practice in combating excessive sodium in the soils.

4. Realization of economic benefits is real driving force in adopting any innovation; therefore, further research on the economic and biologic benefits of sesbania application is required.

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Tab. 1: Chemical analysis of the soil used in amendment study

Parameter	Surface soil (0-15 cm)	Sub soil (15-30 cm)	Parameter	Surface soil (0-15 cm)	Sub soil (15-30 cm)
pH	8.4	8.8	NH_4-N (mg/kg)	5.33	7.03
ECE (dS/m)	8.5	7.8	NO_3-N (mg/kg)	0.59	0.46
SAR	49.5	40.5	P (mg/kg)	6.06	5.96
Org. matter (%)	0.65	0.51	K (mg/kg)	190	170
$CaCO_3$ (%)	0.80	1.30	Fe (mg/kg)	22.7	17.89
Ca (%)	0.22	0.20	Cu (mg/kg)	2.69	2.33
Total-N (%)	0.079	0.079	Mn (mg/kg)	2.1	1.17
			Zn (mg/kg)	1.17	1.2

Tab. 2 : Effect of sesbania green manuring and phosphorus application on rice yield.

P rates (kg/ha)	Productive tiller/plant			Paddy yield (t/ha)			Straw yield (t/ha)		
	No GM	GM	Mean	No GM	GM	Mean	No GM	GM	Mean
0	7.60	9.34	8.47e	1.79	2.13	1.96e	2.88	3.04	2.96d
15	8.47	10.87	9.67d	2.29	2.96	2.63d	3.04	3.38	3.21c
30	9.13	11 47	10.30c	2.63	3.04	2.84c	3.25	3.63	3.44b
60	10.47	12.10	11.28b	3.21	3.50	3.36b	3.33	3.79	3.56ab
90	11.00	12.30	11.65a	3.34	3.73	3.52a	3.42	3.79	3.60a
Means GM	9.33b	11.21a		2.65b	3.07a		3.19b	3.53a	

** Means sharing the same letter are not different at p 0.05*
*** No GM = Sesbania was not added, *** GM = Sesbania was added*

Tab. 3 : Effect of sesbania and phosphorus application on phosphorus concentration in rice

P rates (kg/ha)	P concentration in grain (%)			P concentration in straw (%)		
	No GM	GM	Mean	No GM	GM	Mean
0	0.29	0.247	0.270d	0.167	0.14	0.154d
15	0.30	0.29	0.297c	0.167	0.163	0.165c
30	0.32	0.323	0.322b	0.193	0.197	0.195b
60	0.32	0.33	0.325b	0.187	0.21	0.199b
90	0.32	0.357	0.352a	0.187	0.267	0.227a
Means for GM	0.317a	0.309b		0.180b	0.195a	

Tab. 4 : Effect of sesbania and phosphorus application on phosphorus uptake by rice

P rates (kg/ha)	P uptake in grain (kg/ha)			P uptake in straw (kg/ha)			Total P uptake (kg/ha)		
	No GM	GM	Mean	No GM	GM	Mean	No GM	GM	Mean
0	5.71	5.25	5.48e	4.45	4.26	4.36e	10.16	9.51	9.84e
15	6.94	8.31	7.63d	5.07	5.54	5.31d	12.01	13.84	12.93d
30	8.43	9.79	9.11c	6.30	7.15	6.73c	14.73	16.94	15.84c
60	10.26	11.52	10.89b	6.22	7.59	6.96b	16.48	19.11	17.80b
90	10.22	12.74	11.48a	6.38	8.97	7.68a	16.61	21.71	19.16a
Means GM	8.31b	9.52a		5.70b	6.70a		14.00b	16.22a	

Tab. 5: Effect of sesbania and P application on agronomic efficiency and phosphorus recovery

P rates (kg/ha)	Agronomic efficiency (kg paddy/kg P)			P recovery (%)		
	No GM	GM	Mean	No GM	GM	Mean
15	33.33	55.53	44.33a	12.33	28.89	20.63
30	28.00	30.33	19.17b	15.23	24.75	20.00a
60	23.66	22.83	23.25c	10.53	15.99	13.27b
90	17.22	17.77	17.33d	7.16	13.55	10.35c
Means for GM	20.44b	25.19a		9.05b	16.65a	

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