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Rehabilitation of Problem Soils Through Environmental Friendly Technologies – I: Effect of Sesbania (*Sesbania Aculeata*) and Farmyard Manure

إصلاح لبعض مشاكل التربة عن طريق إتباع أساليب بيئية صديقة : أثر السسبانيا وسماد ساحة المزرعة

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Abstract: Environmental problems due to land degradation in the developing countries have been a matter of great concern for the decades. The rehabilitation of problem lands has been through many chemical means and engineering approaches, that have resulted in enhancing the gravity and the magnitude of the problems. The present studies were undertaken to examine the role of environmental friendly practices to address the salinity issue. The effect of organic manuring (green manure and farmyard manure) on rice (*Oryza sativa*) was investigated in a field study on a saline-sodic soil of the Saline Agriculture Research Station, Sadhuke, Pakistan. Sesbania was grown as a green manuring crop for two months and then incorporated into the soil. Farmyard manure (FYM) was applied at rates of 0, 5, 10 and 20t/ha before the sowing of sesbania. Rice, Cv. Basmati 385, was used as the indicator/test crop. Results revealed that both paddy and straw yields were significantly improved by the application of sesbania and FYM. Green manuring with sesbania improved the paddy and straw yield by 15.4% and 14.5% respectively. Productive tillers were also increased by the application of FYM but differences were not significant between 10 and 20t/ha of FYM application. FYM application also improved the paddy and straw yield significantly. The increases in paddy yield due to application of 5, 10 and 20t/ha of FYM were 6.8%, 24.4% and 37.6% over control, respectively. Nitrogen and phosphorus utilization by rice were also significantly improved with the application of green manure. Nitrogen uptake by rice (grain+straw) was increased by 17.8% and that of phosphorus by 21.9% with the green manuring. Nitrogen uptake was significantly increased by the application of different rates of FYM. Also phosphorus uptake was increased significantly with the application of FYM.

Keywords: Environment, organic manure, problem lands, improvement, reclamation

المستخلص: تعتبر المشاكل البيئية التي سببها تآكل التربة، محط اهتمام الدول النامية في العقود الأخيرة. فهناك العديد من الطرق لاستصلاح الأراضي الزراعية منها : الطرق الكيماوية والطرق الهندسية، لتحسين النوعية والكمية. هناك العديد من الدراسات الحديثة التي بحثت دور الممارسات البيئية الصديقة، لتقديم حل لمشكلة الملوحة. و لقد تم إجراء بحث ميداني لدراسة أثر السماد العضوي (السماد الأخضر وسماد ساحة المزرعة) على أرز (*Oryza sativa*) تربة سالين-سوديك الملحية في المحطة الزراعية للبحث في الباكستان، حيث تم زراعة نبات السسبينيا كسماد اخضر لمدة شهرين وبعدها تم خلط التربة بها. و من ثم تمت اضافة سماد ساحة المزرعة للأراضي المزروعة بنسب 0 ، 5، 10 و 20 طن/هكتار قبل زراعة السسبينيا و لقد تم استخدام الأرز البسمتي 385 كمؤشر للاختبار. أشارت النتائج إلى أن محاصيل الأرز والقصب قد تم تطويرها، وذلك بسبب إضافة السسبينيا. ولقد تم تحسين المحاصيل عند إضافة السماد الأخضر مع السسبينيا بنسبة 15.4% و 14.5%. و لقد تم زيادة إنتاجية الفلاحين بسبب إضافة السماد، لكن الاختلافات لم تكن هامة بين 10 و 20 طن/هكتار لهذه الاضافة. الزيادة في محصول الارز عند إضافة السماد بنسبة 10.5% ، و 20% كان بنسبة 6.8%, 24.4% , 37.6%. كما أن الإفادة من عنصري النيتروجين وعنصر الفسفور للأرز طور من تطبيق السماد الأخضر. فقد ازدادت نسبة امتصاص الأرز لعنصر النيتروجين بنسبة 17.8 % ولعنصر الفسفور بنسبة 21.9% عند اضافة السماد الأخضر. ولقد اعتمدت نسبة امتصاص النيتروجين على إضافة السماد الخضر وبنسب مختلفة. وكذلك الأمر بالنسبة لعنصر الفسفور.

كلمات مدخلية: البيئة ، السماد العضوي، مشاكل التربة، التطوير، الاستصلاح .

Introduction

The pressing need for more food coupled with scarcity of good arable land in Pakistan necessitates expanding farming to marginal lands that lie barren because of undesirable soil conditions. These properties fall into three broad classes: chemical (mainly mineral), physical and hydrological. Mineral stresses that depress crop yields result from soil toxicities and nutrient deficiencies or both. These stresses are more likely to occur in salt-affected and waterlogged soils.

Worldwide, saline soils cover over 380 million hectares. Of that area, 240 million ha are not strongly saline (Massoud, 1974) and consequently have crop production possibilities. About 54 million ha of weakly saline soils are in South and Southeast Asia; about half of this land is in the humid tropics where conditions are climatically, physiologically and hydrologically suited to rice cultivation but are not presently used because of salinity (Verma and Neue, 1984).

The magnitude of salt-affected soils in Pakistan is alarming. Recent data shows that 6.3 million hectares are affected by salinity (Khan, 1993). The arid climatic conditions involving scanty rainfall and high evapotranspiration in the country have led to this unfavorable salt distribution and accumulation in the crop rooting zone (Bajwa, *et al.* 1991).

Salinity and sodicity (excessive levels of soluble salts and exchangeable sodium) adversely affect plant growth either through the direct toxic effects of excess salts in the form of hydrostatic and osmotic stresses, or indirectly by hindering the absorption of water and nutrients. Muhammad (1978) reported 60% of the salt-affected soils in Pakistan and 80% in the Punjab province are saline-sodic. In order to improve the productivity of such soils, reclamation either through chemical amendments or by other means is essential. Because reclamation of salt-affected soils is expensive and time consuming, losses in soil productivity may be reduced by improved crop nutrition and sound management practices, especially the selection of crops well adapted to adverse conditions (Qureshi, 1985).

Rice can be grown successfully under these conditions because of its medium tolerance to salinity, its high water requirement and its adaptability to moderate waterlogged conditions. The standing water of rice paddies dilutes the salts, increases the availability of Fe, Mn, P and S and eliminates water stress (Ponnamperuma and Bandyopadhya, 1980). Sesbania species have been used for the reclamation of saline soils and saline-sodic soils (Evans and Rotar, 1987). Sesbania aculeata is commonly known as 'Dhancha' in Pakistan. The cytoplasmic pH of sesbania is about 4.01 (Uppal, 1955). Therefore, it can neutralize soil alkalinity considerably when buried as green manure (Bajwa, *et al.* 1991). Its ash contains 34.2% CaO (Dhawan, *et al.* 1958). In addition, the oxidation of C to CO_2 results in the formation of carbonic acid, which solubilizes lime and thus helps in the reclamation process (Prichard, *et al.* 1985; Bajwa, *et al.* 1991; Gupta, *et al.* 1988). The latter workers also concluded that removal of exchangeable Na and reduction in soil pH are directly related to the amount of CO_2 production in calcareous sodic soils. In addition, its tap root system may help to improve the water and air conducting properties of problem soils (Yaseen, *et al.* 1990; Bajwa, *et al.* 1991).

In Pakistan, rice-wheat is a very common crop rotation where sesbania fits in well. Sesbania can be planted in May after the wheat harvest and incorporated into the soil at the end of June, two weeks prior to rice transplanting (Yaseen, *et al.* 1990). As a green manure crop, it can substitute for applied fertilizer N (Dargan and Chillar, 1980) in addition to supplying organic matter for the restoration of soil physical conditions. The use of sesbania as green manure (GM) improves soil productivity through biological N 2 fixation (Zia *et al.*, 1992).

Use of organic soil amendments, such as farmyard manure (FYM), a heterogeneous composted organic material consisting of a mixture of dung, crop residues, and/or household sweepings in varying stages of decomposition, is an important component in sustainable agricultural production in many countries (Stinner and Blair, 1990; Tandon, 1990; Motavalli, *et al.* 1994). Such amendments promote sustainability because of:

1. long-term positive effects on chemical and physical properties of soil (Khaleel, *et al.* 1981; Agboola, 1982; Lee and Wani, 1989);
2. recycling plant nutrients within a farm, e.g. feeding harvested fodder to livestock and then applying FYM from those animals back to the land (Parker, 1990);
3. substitution of readily available organic inputs for chemical fertilizers and, therefore, a decreased dependence on costly external sources (King, 1990);

4. general improvement in crop yield and quality obtained when adequate rates of organic soil amendments are incorporated into the soil (Nambiar and Abrol, 1989). In addition to supplying major and micronutrients, FYM also adds organic matter to the soil, helping to increase productivity by improving soil structure and reducing soil pH (Zia, *et al.* 1992) and sodicity (Gupta, *et al.* 1988).

Different agro-forestry practices have been successfully used in many parts of the world on marginal lands under different climatic conditions. It has been observed in other areas that the growing of crops and the mixing of fresh plant matter and organic residues into saline soils can release plant nutrients by lowering the soil pH and producing root exudates (Mercks, *et al.* 1986; Christensen, 1987; Marschner, *et al.* 1987; Yodkeaw and De Datta, 1989; Treeby, *et al.* 1989).

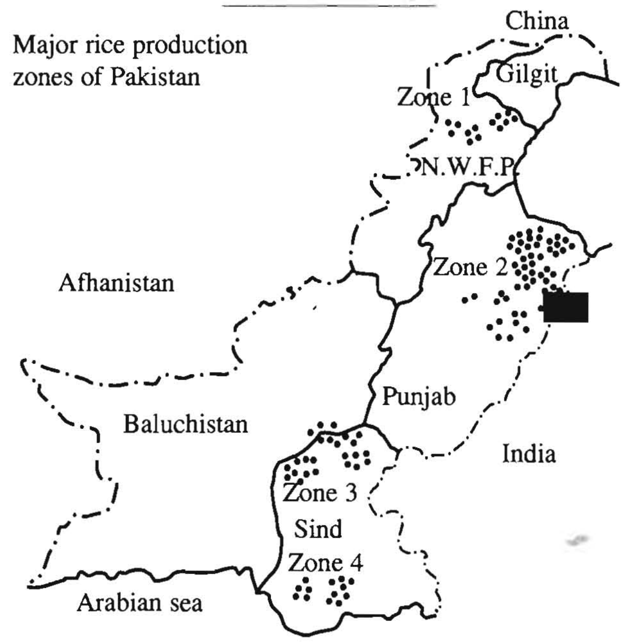
Surprisingly, there is a lack of data in the literature relevant to Pakistan, demonstrating the combined effect of plants and organic residues on the mobility and solubility of nutrients in saline-sodic soils. Therefore, the present study was undertaken with two main objectives:

(1) to set the stage for reclaiming salt-affected soils through environmental friendly technologies, i.e. agro-forestry, growing rice and sesbania simultaneously to reduce salt loading and avoiding chemical fertilizers and amendments;

(2) to evaluate this technology for its effectiveness in enhancing rice yields and in improving the nitrogen and phosphorus nutrition of rice growing on a dense saline-sodic soil.

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° 18′ E longitude and 31° 35′ N latitude in the northeastern portion of the Indus plain and the site is 702 ft above the sea level. 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 natural or artificial drainage outlet, salt accumulation in soils resulted (Ilyas, 1990).



Climate and Soils

The study area has an arid and continental climate with an average temperature of 24°C. The summer months in the area are really hot with temperatures in the range of 35-40°C and mean annual rainfall is from 325-750 mm. In early summer, before the start of the monsoon season, potential evaporation is several-fold larger than precipitation (Khan, 1991). The soil at the study site is a fine-loamy, mixed, thermic Typic Natrustalf.

The chemical analysis of soil from the experimental area is shown in Table 1. The soil of the site is alkaline, calcareous and saline-sodic in nature. It is deficient in nitrogen (0.07%) and organic matter (0.5%); however, potassium and other micronutrients are adequate. It is believed that healthy soils should contain >1.0 % organic matter and total nitrogen and phosphorus levels should exceed 10 mg/kg to be able to sustain economic yields. Good quality water fit for drinking and suitable for irrigation purposes has been made available by installing a tube well on the farm.

Table 1. Chemical analysis of the soil used in the amendment study

Parameter	Surface soil (0-15 cm)	Sub soil (15-30 cm)
pH	8.4	8.8
ECe (dS m-1)	8.5	7.8
SAR	49.5	40.5
OM (%)	0.65	0.51
$CaCO_3$ (%)	0.80	1.30
Ca (%)	0.22	0.20
Total-N (%)	0.07	0.07
NH_4-N(mg/kg)	5.33	7.03
NO_3-N(mg/kg)	0.59	0.46
P (mg/kg)	6.06	5.96
K (mg/kg)	190.00	170.00
Fe (mg/kg)	22.70	17.89
Cu (mg/kg)	2.69	2.33
Mn (mg/kg)	2.10	1.17
Zn (mg/kg)	1.17	1.20

Materials and Methods

Experimental Design, Treatments and Other Procedures

The experimental design was a randomized complete block (RCB) design with three replications. The following treatment combinations were employed to devise environmental friendly technologies.

- T1 No GM + No FYM (control)
- T2 No GM + 05 t/ha FYM
- T3 No GM + 10 t/ha FYM
- T4 No GM + 20 t/ha FYM
- T5 GM + No FYM
- T6 GM+ 05 t/ha FYM
- T7 GM + 10 t/ha FYM
- T8 GM + 20 t/ha FYM

Sesbania was grown and incorporated into the soil as GM with a rotavator two months after application of FYM. After flooding, rice (variety Basmati 385) was grown in the 6 x 6 metre plots until maturity under the eight treatments shown above. To ensure better growth of sesbania and the following rice crop, nitrogen in the form of urea and phosphorus as single super phosphate (SSP) were applied at the rates of 80 and 50kg/ha, respectively. Two thirds of the nitrogen and all of the phosphorus were applied at the time of rice transplantation. The remainder of the nitrogen was applied at the time of panicle initiation. The crop was harvested at maturity. Data on productive tillers, paddy and straw yield were recorded at the time of harvest. Nitrogen and phosphorus levels in rice grain and straw were determined. Rates of uptake were calculated by multiplying the nutrient concentrations in the tissue by their respective yields; total uptake was the sum of grain and straw values. Nitrogen was determined by the Kjeldahl method and phosphorus colorimetrically (Prevel, *et al.* 1987).

Statistical Analysis

The experimental data for all plant parameters were analyzed statistically, using analysis of variance (ANOVA) with a SAS Program (SAS Institute, 1985). Treatment means were compared by applying Duncan's Multiple Range Test (DMRT) (Duncan, 1955). An alpha level of 0.05 was specified for all comparisons.

Results and Discussion

Effect of Sesbania and Farm Yard Manure on Rice Yields

Data on the effect of sesbania green manure (GM) and farmyard manure (FYM) on productive tillers, paddy and straw yields are shown in Fig 1. Sesbania green manuring had significant effects on tiller production. Paddy and straw yields increased 15.4% and 14.5%, respectively, by green manuring. This indicates that sesbania produced tillers with more weight and grains. This may be attributed to a greater amount of N2 fixation and consequent accumulation and uptake from the soil. Somani and Saxena (1981) found that total microbial counts increased with sesbania green manure more than with FYM, poultry manure, or rice husks. It is assumed that these amendments fix N2 and thus enhance fertility of the soil. Similar results have been reported under different climatic conditions by Rao Subba (1993), Evans and Rotar (1987), and Sharma and Das (1994).

Productive tillers (Fig.1a) were significantly higher when the initial applications of FYM were 20 and 10t/ha, while differences due to 5 t/ha were not significant compared to the control. The physical conditions of the sodic soil might have improved because FYM increased the number of tillers. Paddy and straw yields increased significantly with higher rates of FYM application. As shown in Fig.1b, the increases in paddy yield due to application of 5, 10 and 20t/ha FYM were 6.8%, 24.4% and 37.6%, respectively; increases in straw yield were 7.2%, 15.7% and 19.55%, respectively (Fig. 1c). Studies conducted by other workers (Meelu, *et al.* 1991; Motavalli, *et al.* 1994) reveal that FYM has considerable positive effect on the physical properties of the soil, which may have translated into an increase in yield.

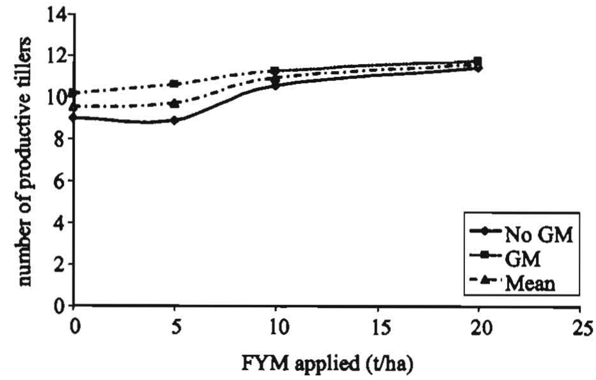


Fig. 1a: Effect of sesbania and FYM on productive tillers/plant

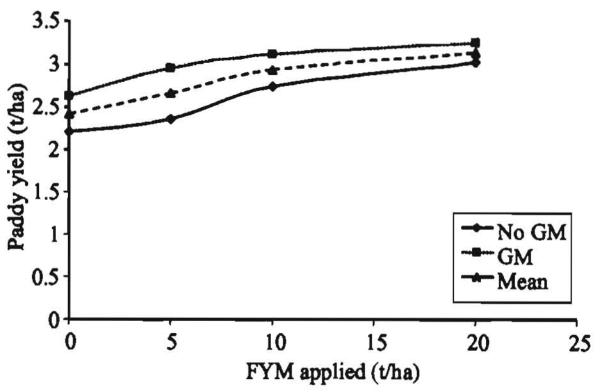


Fig. 1b: Effect of sesbania and FYM on paddy yield

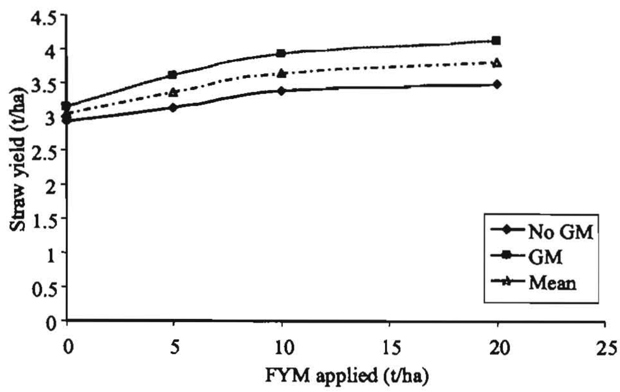


Fig. 1c: Effect of sesbania and FYM on straw yeild (t/ha)

Effect of Sesbania and Farm Yard Manure on Nitrogen Concentration in Rice

Nitrogen concentrations in rice grain and straw were not affected by green manuring (Table 2), but were significantly affected by FYM at all rates of application. Differences in N concentration in both rice grain and straw due to 20 and 10, 10 and 5, and 5 and 0t/ha of FYM were not significant. FYM was probably low in available nitrogen content and as a result did not improve nitrogen concentration. FYM has been reported to be a poor source of plant nutrients (Motavalli, *et al.* 1994). Moreover, straw is the main constituent of FYM and has a wide C:N ratio that reduces nitrogen availability (Hussain, *et al.* 1988). In addition, the nitrogen-containing organic compounds in FYM are much more resistant to decomposition and only 1/3 of the nitrogen is easily released (Cooke, 1972). The remaining nitrogen can persist in the soil for a longer period, but the decomposition rate of soil organic matter depends on organic matter type and especially on the proportion of non-hydrolysable substances. These are relatively higher in FYM (Mengel and Kirkby, 1987).

Table 2. Effect of sesbania and farmyard manure on nitrogen concentration in rice

FYM applied (t/ha)	N concentration in grain (%)			N concentration in straw (%)		
	No GM	GM	Mean	No GM	GM	Mean
0	1.04	1.08	1.06b	0.63	0.657	0.645c
5	1.16	1.22	1.19ab	0.653	0.68	0.667bc
10	1.16	1.24	1.20 ab	0.7	0.737	0.720ab
20	1.19	1.28	1.23a	0.737	0.77	0.755a
Means for GM	1.14a	1.20a		0.680a	0.711a	

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

Effect of Sesbania and Farmyard Manure on Phosphorus Concentration in Rice

Phosphorus concentrations in rice grain and straw were significantly affected by the application of GM and at all rates of FYM (Table 3). Treatment means of 5 and 10t FYM/ha did not differ significantly from each other in rice grain, nor was phosphorus concentration in rice straw significantly affected by FYM application at rates of 10 and 20t/ha. Phosphorus has the role of strengthening the straw of cereal crops and preventing lodging (Brady, 1984), and the observed increase in phosphorus concentration in straw may be related to that role. The data are in agreement with a similar study conducted under different environmental conditions (Mor and Manchanda, 1992).

Table 3. Effect of sesbania and farmyard manure on phosphorus concentration in rice

FYM applied(t/ha)	P concentration in grain (%)			P concentration in straw (%)		
	No GM	GM	Mean	No GM	GM	Mean
0	0.3	0.293	0.297c	0.173	0.19	0.182c
5	0.307	0.324	0.315b	0.197	0. 23	0.214b
10	0.317	0.337	0.327b	0.233	0.253	0.243a
20	0.35	0.373	0.362a	0.24	0.257	0.249a
Means for GM	0.319b	0.332a		0.211b	0.233a	

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

Effect of Sesbania and Farm Yard Manure on Nitrogen Uptake in Rice

Nitrogen uptakes in rice grain, straw and in grain + straw were all significantly increased by green manuring (Table 4). Tiwari, *et al.* (1980) reported an increase in nitrogen uptake in rice grain due to sesbania green manuring. Panda, *et al.* (1991) reported that sesbania increased yield of the subsequent rice crop due to high N accumulation and greater uptake, and showed a greater release of nitrogen from sesbania green manure than FYM, indicating a higher agronomic efficiency. They observed an increased availability of nitrogen from sesbania green manure during the active vegetative growth period of the rice crop. Higher availability likely resulted in greater nitrogen uptake in rice.

Nitrogen uptake in rice grain, straw and grain+straw was significantly increased with each successive increase of FYM, from 0-5, 5-10, 10 to 20t/ha with the single exception of an increase from 10 and 20 t/ha in rice straw.

Table 4. Effect of sesbania and farmyard manure on nitrogen uptake by rice

FYM applied (t/ha)	N uptake in grain (kg/ha)			N uptake in straw (kg/ha)			Total N uptake in grain + straw (kg/ha)		
	No GM	GM	Mean	No GM	GM	Mean	No GM	GM	Mean
0	22.4	28.4	25.4d	18.4	20.7	19.5c	41.2	49.0	44.9d
5	27.3	36.1	31.7c	20.4	24.5	22.4b	47.8	60.6	53.5c
10	31.8	38.6	35.2b	23.6	28.3	25.9a	55.4	66.9	61.1b
20	36.2	41.2	38.7a	25.7	25.5	25.6a	61.9	66.7	65.6a
Means for GM	29.4b	36.1a		22.0b	24.8a		51.1b	61.4a	

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

Effect of Sesbania and Farm Yard Manure on Phosphorus Uptake

Green manuring did not impact phosphorus uptake in rice grain but had significant effect on straw and as a result, total phosphorus uptake was significantly increased (Table 5). It has been reported that green manuring caused increased utilization of phosphorus by the crop from the reserve supplies of soil phosphorus and also reduced sorption capacity of the submerged rice soil (Hundal, *et al.* 1988). Sesbania green manure probably caused these soil modifications and in turn greater total phosphorus uptake was experienced. Phosphorus uptake in rice grain, straw and grain + straw was significantly affected by the application of FYM. Highest uptakes were recorded with the application of 20t/ha of FYM. Significant differences in phosphorus uptake due to treatments of 20 and 10, 10 and 5 and 5 and 0t/ha of FYM were obtained. The study revealed that FYM improved the phosphorus nutrition on alkaline calcareous sodic soil, although Mengel and Kirkby (1987) reported that FYM was low in available phosphorus as it contained a high proportion of straw.

Table 5. Effect of sesbania and farmyard manure application on phosphorus uptake by rice

FYMAppliedt/ha	P uptake in grain (kg/ha)			P uptake in straw (kg/ha)			Total P uptake in grain + straw (kg/ha)		
	No GM	GM	Mean	No GM	GM	Mean	No GM	GM	Mean
0	6.6	7.7	7.1d	5.1	6.0	5.5d	11.7	13.7	12.7d
5	7.3	9.7	8.5c	6.1	8.3	7.2c	13.4	18.0	15.7c
10	8.7	10.3	9.5b	7.9	10.0	8.9b	16.6	20.3	18.4b
20	10.6	12.2	11.4a	8.4	10.6	9.5a	19.0	22.8	20.9a
Means for GM	8.3a	10.0a		6.9b	8.7a		15.2b	18.7a	

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

Conclusions and Recommendations

1. Sesbania green manuring proved a better reclamant than FYM. Higher grain and straw yields were recorded with sesbania treated plots.
2. Sesbania enhanced nitrogen and phosphorus nutrition by releasing and accumulating nutrients in the soil.
3. The use of FYM as an organic soil amendment is impaired by its low supply and release rate of nutrients.
4. FYM may have improved soil physical properties.
5. The improvement attributed to both the amendments in reclaiming saline-sodic soil is low but soil health and plant nutrition may be improved by introducing sesbania permanently in the rotation.
6. Further research is needed to optimize both economical and biological factors that could make sesbania a permanent feature of the rice-wheat cropping sequence in salt-affected soils of Pakistan.

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