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EFFECT OF GREEN MANURE *(SESBANIA ACULEATA)* ON PHYSICAL PROPERTIES OF SOIL AND GROWTH OF WHEAT IN RICE-WHEAT AND MAIZE-WHEAT CROPPING SYSTEMS

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A b s t r a c t. A field experiment was conducted during 1978-81 to study the effects of green manure (Sesbania aculeata) incorporation in wetland rice and maize on soil physical properties, and root growth and yield of following wheat on a loamy sand soil under sub-tropical climate of northern India. Application of green manure tö wetland rice increased the water stable aggregates, reduced the soil bulk density and increased infiltration rate. The effects of green manure in maize were relatively small.

INTRODUCTION

In northern India, winter wheat mainly follows summer crops of rice and maize. In recent years, larger areas have been brought under rice than maize cultivation due to assured irrigation supplies and better economic returns. Repeated puddling and soil submergence during rice growth, in general, destroys soil aggregation and results in increased bulk density and reduced hydraulic conductivity [4,12,13]. Total amounts of wheat roots an their distribution were affected adversely by the presence of high bulk density layer at 5-25 cm depth in the rice fields [12]. Wheat yields thus following rice have been reported to be lower than following maize [6]. The decrease in yield was attributed to deterioration of surface soil structure and greater nutrients removal by rice than maize.

The most important contribution of leguminous green manures has been the increased input of N to the system [7]. The favourable effects on soil physical properties of incorporating green manuring crops have been reported in literature [5, 8, 10]. Green manuring may help in reducing the deleterious effects of growing rice on soil physical properties. However, little information is available in literature on these aspects.

The objectives of this study were: 1) to determine the effect of green manuring of rice and maize crops on physical properties of the soil and 2) to evaluate the influence of preceding crop on root growth and yield of wheat crop.

MATERIALS AND METHODS

Field investigations were undertaken for three years from 1978 to 1981 at Punjab Agricultural University, Ludhiana (30°56' N 75°52' E, 247 a.s.l.), India. The soil of the experimental site was deep, well drained and loamy sand in texture (Typic Ustipsamment). It was calcareous non-saline with pH 8.4; EC 0.18 dS m^{-1}; organic carbon 0.18 %; available N 101 kg ha^{-1}; Olsen P 26 kg ha^{-1} and ammonium acetate extractable K 142 kg ha^{-1}.

The experiment was laid out in a split design with four replications. The four treatments comprising all combinations of two wetland crops (rice and maize) and two levels of manure (no green and green manure) were randomized in main plots in the summer. In winter, residual effect of *kharif* treatments was studied on succeeding wheat crop. The wheat was grown with four rates of nitrogen: 0, 60, 120 and 180 kg N ha^{-1} applied in sub-plots. The interaction effects of main treatments and N levels were not significant on growth of wheat. The data reported for root growth, and yield of wheat have, therefore, been averaged across N levels. *Sesbania aculeata* as green manure was sown each year in the first week of May. Sixty-day-old *Sesbania* was incorporated in the soil 5-6 days before transplanting of rice. Transplanting of rice variety PR-106 and seeding of maize variety Ageti-76 were made in second week of July in each year. To both rice and maize crops recommended dose of fertilizers (120 kg N, 26 kg P and 25 kg K ha^{-1}) were applied. Wheat variety WL-711 was sown in the second fortnight of November at 22.5 cm row spacing.

During 1978-79 and 1979-80 after rice and maize harvest the bulk density was determined down to 30 cm in 5 cm depth increments using aluminium cores (7 cm ID and 5 cm high). Water intake studies were made by using double ring infiltrometers of 35 to 40 cm diameter of inner rings and 28 cm high. Initially water intake was recorded at short intervals to highlight the soil surface conditions and then at longer intervals till five hours. Wet sieving method was employed to determine the water stable aggregates. The moisture content of soil in different layers (0-5, 5-15, 15-30, 30-60 and 60-90 cm depth) was determined gravimetrically 24 h after pre-sowing irrigation applied to wheat.

Roots of wheat at maturity were determined in 1980-81. Root samples were taken from 0-5, 5-10, 10-30 and 30-60 cm depth using 7.5 cm ID steel tube. These samples were washed with gentle spray of water over 2 mm sieve. Washed roots were picked-up by forceps and rewashed throughly in a beaker; oven dried at 60 °C and weighted. Root density was expressed as the weight of roots per unit volume of soil.

RESULTS AND DISCUSSION

Soil aggregation

In the absence of green manure, water stable aggregates of different sizes were markedly reduced after rice than after maize (Table 1). The process of puddling by wet ploughing and harrowing operations caused break-down of the soil aggregates. Soil structure is reported to be adversely affected by the practices of cyclic puddling, submergence and drying [4,9,15]. Incorporation of green manure considerably improved aggregate stability with more effects after rice. The amount of water stable aggregates between 0.1 and 0.5 mm sizes were increased by about 22 and 62 % (mean of two years), after maize and rice crops, respectively. Under simulated tropical climate, Yaacob and Blair [16] found marked increase in the stability of aggregates 2 mm of the granite soil on which legume crops had been grown. Liu [5] reported increased stability of aggregates in the plots under green manured rice. It has been suggested that green manure can cause great improvement in soil aggregation in soils of poor initial soil structure [14]. The decomposition products of green manure and increase in organic matter levels are not likely responsible for aggregate stabilization. The data showed no cumulative effect of green manure on aggregate stability. Therefore, for improvement in aggregate stability of soil, annual applications of green manure will be required.

Bulk density

Bulk density of the soil in 5 to 25 cm layers was higher after rice than after maize during both the years (Table 2). Repeated

Table 1. Effect of green manuring in rice and maize on water stable aggregates

Treatment		Water stable aggregates (%)					
Crop	Green manure	>0.5	0.5-0.25	0.25-0.1	>0.5	0.5-0.25	0.25-0.1
		mm			mm		
		1978			1979		
Rice	-	3.5	7.1	8.6	3.9	9.4	10.5
Rice	+	3.9	11.3	15.7	4.6	12.8	17.3
Maize	-	4.2	13.8	17.4	4.6	12.8	17.3
Maize	+	4.9	17.8	19.7	5.2	16.7	20.4

Table 2. Effect of green manuring in rice and maize on bulk density of soil bulk density (g cm^{-3})

Treatment		Soil depth (cm)					
Crop	Green manure	0-5	5-10	10-15	15-20	20-25	25-30
				1978			
Rice	-	1.54	1.61	1.67	1.72	1.64	1.62
Rice	+	1.53	1.57	1.61	1.65	1.61	1.60
Maize	-	1.55	1.59	1.62	1.64	1.63	1.60
Maize	+	1.54	1.58	1.61	1.62	1.56	1.56
				1979			
Rice	-	1.50	1.62	1.63	1.69	1.65	1.64
Rice	+	1.48	1.52	1.59	1.61	1.62	1.60
Maize	-	1.52	1.57	1.60	1.65	1.63	1.64
Maize	+	1.50	1.56	1.59	1.63	1.60	1.58

puddling and soil submergence during rice growth increased bulk density, particularly in 15-20 cm layer [12].

Green manure decreased bulk density of the soil after both rice and maize crops, with greater effects after rice. An improvement in soil aggregation due to green manuring was perhaps mainly responsible for the reduction in soil bulk density. Ram and Zwerman [11] found that difference in aggregate stability were associated with bulk density changes. Addition of organic matter through root and tops of green manure perhaps caused a reduction in bulk density of soil. De Hann [3] also observed a decrease in bulk density of soil, particularly in a sandy soil. Green manure application to rice caused sufficient changes in soil bulk density to bring it very close to maize plots.

Infiltration

In all treatments, cumulative infiltration (I;cm) increased as function of time (t;min.), according to the relationship: $I = a\,t^b$ where a and b are constants. The value of a (i.e., total infiltration after 1 min) was higher in rice than in maize during both the years, which means that soil surface conditions in the former were more favourable for infiltration (Table 3). Extensive cracking of the surface soil under rice facilitated the rapid entry of water into the soil. The increase in the rate of cumulative infiltration

Table 3. Effect of green manuring in rice and maize on water infiltration parameters of soil according to the relationship I=a+b

Treatment		1978			1979		
Crop	Green manure	a*	b	r	a	b	r
Rice	-	1.47	0.42	0.98	1.82	0.35	0.79
Rice	+	1.58	0.41	0.99	1.86	0.40	0.98
Maize	-	0.71	0.56	0.99	1.34	0.48	0.99
Maize	+	0.68	0.61	0.99	1.24	0.51	0.99

*a and b - constant coefficient.

was higher after maize than after rice crop. On unamended plots, cumulative infiltration ofter 300 min was 89 and 62 mm higher after maize than after rice crop during 1978 and 1979, respectively.

Application of green manure had no affect on the water infiltration rate of the soil after maize (Table 4). On the other hand, green manuring with *Sesbania* increased the rate of infiltration of water during both the years. The differences in infiltration rate on no green manure and green manure amended plots were larger initially (up to 60 min) and decreased thereafter. After 300 min, cumulative infiltration in green manured plots with rice increased by 47 and 59 mm over no green manure treatment during 1978 and 1979, respectively. Cumulative infiltration after 300 min was 47 and 59 mm greater in green manured than that in no manured rice plots during 1978 and 1979, respectively. In this study, green manuring increased aggregate stability and reduced bulk density of soil after rice which possibly increased the rate of water infiltration. Several authors have reported favourable improvement in infiltration when aggregate stability was also increased [1,2].

Soil water storage

Soil water content determined 24 h after irrigation in 0-5 cm layer was greater under rice than under maize (Table 5). On the other hand, in 15 to 90 cm soil layers maize plots retained considerably higher water content than rice plots. Soil water storage to 90 cm depth was 14 cm more in maize than in rice plots. Lower soil water suction and increased microporosity caused by disruption of surface soil structure in rice field could be the reasons for retaining more water in the surface soil layers. The downward unsaturated movement in the soil of unpuddled rice plots as compared to saturated movement in the unpuddled maize plots probably caused low water content in the 15 to 90 cm layers [12].

Growing and incorporation of *Sesbania* green manure in rice plots increased soil

Table 4. Infiltration rate of water (mm min^{-1}) as affected by preceeding crop and green manure (GM)

Time (min)	1978				1979			
	Rice		Maize		Rice		Maize	
	-GM	+GM	-GM	+GM	-GM	+GM	-GM	+GM
2	0.41	0.43	0.29	0.32	0.41	0.43	0.45	0.45
10	0.16	0.17	0.14	0.19	0.14	0.16	0.19	0.20
20	0.11	0.11	0.11	0.13	0.09	0.11	0.14	0.15
60	0.06	0.06	0.06	0.08	0.04	0.06	0.08	0.08
120	0.04	0.04	0.05	0.06	0.03	0.04	0.05	0.06
300	0.02	0.02	0.03	0.05	0.02	0.02	0.03	0.04

Table 5. Effect of green manuring in rice and maize on soil water content and total water storage at sowing of wheat (1980-1981)

Treatment		Soil water content (%) at the depth (cm)					Soil water storage (mm)
Crop	Green manure	0 - 5	5 - 15	15 - 30	30 - 60	60 - 90	0 - 90
Rice	-	19.3	20.1	16.4	16.0	16.0	150
Rice	+	18.0	20.2	18.0	18.4	18.5	167
Maize	-	14.2	20.3	17.3	18.2	18.4	164
Maize	+	14.6	20.4	18.0	18.4	18.3	166

water storage by 17 mm to 90 cm depth over no green manure plots. Improvement in soil structure and a decrease in bulk density of soil due to green manuring were most likely associated with the increase in soil water content in 15 to 90 cm profile. Green manure had no effect on soil water storage in maize plots.

Root growth and yield of wheat

In the absence of green manure, weight density of wheat roots was greater after maize than after rice in 5 to 60 cm layers determined at maturity (Fig. 1). In the 0-5 cm layer, there were, however, more roots in rice-wheat than in maize-wheat rotation.

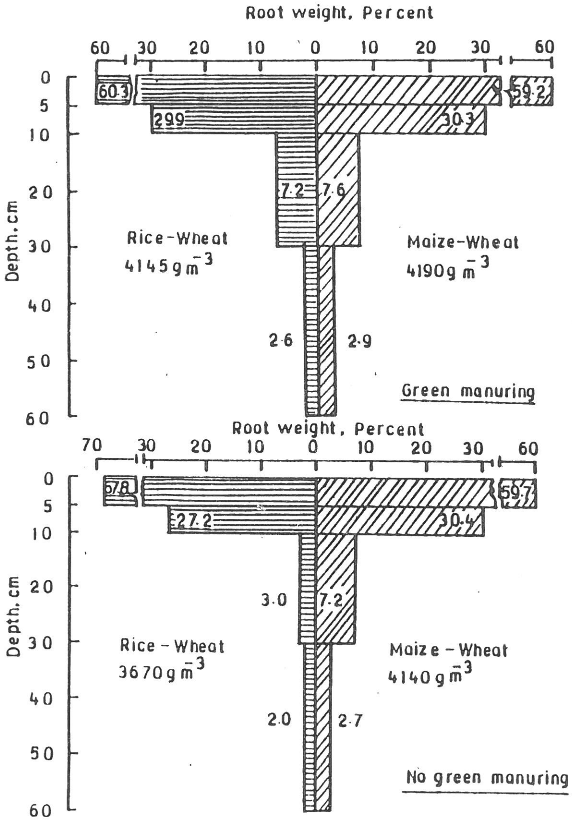

Fig. 1. Root distribution of wheat at harvest during the years 1980-1981.

Table 6. Effect of green manuring in rice and maize on the grain yield of succeeding wheat crop

Treatment		Grain yield (t ha^{-1})			
Crop	Green manuring	1978-79	1979-80	1980-81	Mean
Rice	-	3.53	4.14	3.49	3.72
Rice	+	3.94	4.48	3.61	4.01
Maize	-	3.79	4.37	3.62	3.93
Maize	+	3.93	4.49	3.76	4.06
LSD (0.05)		0.18	0.18	NS	-

Total root mass in the 0-60 cm profile after maize was 12.8 % more than after rice. This indicates that conditions for wheat root growth were more favourable in the maize than in the rice plots. The amounts of root decreased with depth after both crops, but the decrease was greater in rice plots, especially in the 10-30 cm layers.

This decrease seems to be associated with the mechanical impedance caused by the higher bulk density of the layer and the less favourable moisture regime resulting from the changes in drainage characteristics. In the 10-30 cm layer the relative amount of roots in the maize plots were 190% more than that in the rice plots. This poor distribution of wheat roots in the profile after rice compared with the maize plots might have adversely affected the use of water and nutrients from the profile. This resulted in 7.2 % (mean of 3 years) lower wheat yield in rice than maize plots (Table 6).

Incorporation of green manure markedly increased root density of wheat grown after rice. It resulted in similar weight density of roots in maize and rice plots. Green manure had no effect on root growth in maize plots. The increase in root density due to green manuring of rice could be ascribed to the improvement in the soil physical conditions. The wheat yields obtained after green manured rice and maize plots were almost similar.

CONCLUSIONS

Growing and *in-situ* incorporation of leguminous green manure crop before rice transplanting can help to improve physical properties of soils under wetland rice. Green manuring thereby resulted in improved root growth of the following wheat crop. Apart from beneficial effects in rice, adoption of green manuring practice in rice-wheat rotation will help in obtaining optimum yields of the following crop of wheat.

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