The effect of soil amendments and soil structure on minimizing constraints of lowland soils on growth of mungbean and peanut under glasshouse condition

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Abstract

Crop diversification following wet season rice is one avenue of increasing agricultural productivity in Cambodia. Lowland rice soils have numerous physical and chemical constraints to non-rice crop production. A glasshouse pot experiment was conducted during dry season from January to April 2010 at the Cambodian Agricultural Research and Development Institute (CARDI). An omission pot trial investigated the effect of soil structure, soil fertility, soil pH, lime, and straw mulching on growth of mungbean and peanut. Results showed that at flowering time, the omissions of rice straw mulching and chemical fertilizer application had the largest effect followed by omission of cow manure application on growth of mungbean and peanut, while omission of either lime or disturbed soil structure reduced growth, but the effect was small and not significant. At final harvest stage, the omission of chemical fertilizer application still has the large effect on the total dry matter of mungbean and peanut, followed by lime application and straw mulching.

Keywords

Vigna radiate, Arachis hypogaea, soil constraints, disturbed and undisturbed soil

Introduction

Legumes are traditionally grown in Cambodia as rainfed wet season crops on upland soils. There is tremendous potential for non-rice crops to be grown also on lowland rice soils following wet season rice, using residual soil moisture and supplementary irrigation systems in the dry season on well drained sandy soils (Nesbitt, 1997). Under rainfed lowland conditions, the paddy field is commonly left fallow during the dry season. However, legumes are occasionally grown as an opportunity crop with very little inputs and yields are therefore very low; 0.3-0.8 t/ha in experiments in other countries (Kirchhof *et al*., 2000). The establishment of legumes into lowland rice-based cropping systems offers the opportunity to increase sustainable productivity and income of farmers in rainfed lowland rice production areas of South East Asia (Kirchhof *et al*., 2000).

However, there are numerous agronomic constraints to the production of dry season legumes after rice. The puddled soil, with associated soil compaction, soil surface crusting, and a hard plough pan, is a major cause of low crop establishment and poor early growth. In addition, the inherent low soil fertility and acidity of most Cambodian lowland rice soils also contributes to the low grain yield of legumes. High soil strength is closely related to soil compaction and increased soil bulk density, and also to reduction of soil water content and low organic matter within the soil. A pot experiment was conducted to evaluate the effectiveness of soil amendments of chemical fertilizer, cow manure, lime, rice straw, and soil structure to minimizing constraints of lowland soils on growth and yield components of mungbean and peanut.

Materials and methods

A glasshouse pot experiment was conducted during dry season from January to April 2010 at CARDI. The standard treatment (All) consisted of application of the soil amendments of cow manure, chemical fertilizer, lime, and straw mulch, while the other treatments consisted of the standard with one amendment omitted from each pot as outlined in Table 1. The soil for the experiment was taken from the top soil (0-20 cm) from areas where rice crop was grown during rainy season. In the field, a hardpan existed at 20 cm therefore in each pot we established a soil depth of 20 cm. As such, the twenty litre (20 cm wide x 25 cm height) black plastic pots were packed with 11 kg of air-dried sieved soil (disturbed soil) or 12.5 kg of undisturbed soil (maintaining paddy structure and field water content) of a Prateah Lang (PL) soil (Seng *et al*, 2008). This 1.5 kg difference in soil weight between disturbed and undisturbed soil, was largely due to water content of the undisturbed soil cores. Pots were maintained at field capacity for the duration of the experiment, and therefore it is likely that potential differences in water and nutrient availability due to differences in initial soil weight in the pots was negligible.

The pot experiment was a split plot design with two legumes (mungbean and peanut), considered main plot and eight soil amendments as subplot treatments with three replications. Five seeds of mungbean and peanut were sown (2-3 cm depth) on 9 January, thinned to 2 plants per pot after 2 weeks. Mungbean reached maturity and was harvested on the 13th of March, while peanut was harvested on 25th of March prior to maturity. One litre of water was applied daily per pot. Root length, root dry weight and total plant dry weight were measured for one plant at flowering (33DAS), and one plant at final harvest.

Soil amendments were allocated to two soil structures, either disturbed (DS+) or undisturbed (DS-) soil, and incorporated to different depths, as described in Table 1. The standard treatments were, all amendments applied, consisting of; 1) cow manure used as organic matter (OM) applied at 5 tons per hectare; 2) rice straw (ST) on the soil surface at the rate of 5 tons per hectare; 3) chemical fertilizer (CF) at the rate of 36 kg/ha of N, 130 kg/ha of P_2O_5 and 50 kg/ha of K_2O, and 4) lime (L) applied at 0.5 tons per hectare. The Nil treatment consisted of no soil amendment addition and undisturbed soil structure.

The decision to use 0.5 t/ha of lime application was the result of preliminary testing of different levels of lime application tested before the pot experiment started. The original soil pH for this pot experiment was 5.5, and when the three levels (0.8 t/ha, 1 t/ha, and 1.2 t/ha) of lime were applied, soil pH was increased by 1.90, 3.50, and 3.54 units, respectively. In this case, 0.5 t/ha of lime was selected to improve the soil pH from 5.5, aiming to achieve pH of 6.5.

Table 1: Treatments used in glasshouse experiment on Mungbean and Peanut crops: All, All+Whole mixing are standards; disturbed soil (DS); organic matter (OM); rice straw (ST); lime (L) and chemical fertiliser (CF); + indicates inclusion and – indicates without; Soil mixing depths indicated as whole (0-20cm); top half of pot (0-10cm); 3cm of sieved soil added to undisturbed soil surface (0-3cm)

Soil applications:	Standard All + whole mixing	Standard +All	All-DS	All-OM	All-ST	All-L	All-CF	Nil
Soil mixing depth	(0-20 cm)	(0-10cm)	(0-3cm)	(0-10cm)	(0-10cm)	(0-10cm)	(0-10cm)	
Disturbed soil (DS)	+	+	-	+	+	+	+	-
Organic matter (OM)	+	+	+	-	+	+	+	-
Rice straw (ST)	+	+	+	+	-	+	+	-

Lime (L)	+	+	+	+	+	-	+	-
Chemical fertiliser (CF)	+	+	+	+	+	+	-	-

Results

Root mass

Both crop and treatment main effects were significant ($p<0.05$) at final harvest stage on the root dry weight, with a significant crop effect at flowering (Table 2). A significant treatment by crop interaction effect only existed at flowering. On average the root weight in peanut was 0.07 g and 0.30 g higher than mungbean at flowering and final harvest respectively.

At flowering stage, the All-ST and Nil treatments produced the lowest root dry weight however, the Nil treatment for peanut was among the highest root dry weight. Similarly, the highest root dry weight was All+ Whole mixing for mungbean, while All and All-CF achieved the highest root dry weight for peanut. In peanuts, All-ST produced smallest amount of root dry weight at 0.13 g.

At final harvest, both crops responded similarly to soil amendments with the All-DS (0.55 g) having the highest root dry weight which was significantly greater than All-OM (0.49 g) and the All and All+whole mixing treatments. The Nil and All-CF produced the lowest root dry weight (0.28 g).

Table 2: Mean root dry weight (g/plant) of mungbean and peanut at flowering and final harvest for eight treatments (All+Whole mixing, and All are standards; All-disturbed soil (All-DS); All-organic matter (All-OM); All-rice straw (All-ST); All-lime (All-L) and All-chemical fertiliser (All-CF).

Treatment	Flowering			Final harvest		
?	Mungbean	Peanut	Mean	Mungbean	Peanut	Mean
All+ Whole mixing	0.15	0.15	0.15	0.28	0.61	0.45
All	0.13	0.21	0.17	0.24	0.64	0.44
All – DS	0.12	0.16	0.14	0.48	0.61	0.55
All – OM	0.13	0.15	0.14	0.31	0.66	0.49
All – ST	0.06	0.13	0.10	0.16	0.53	0.35
All – L	0.12	0.20	0.16	0.15	0.56	0.36
All – CF	0.09	0.22	0.16	0.20	0.36	0.28

Nil	0.06	0.20	0.13	0.16	0.39	0.28
Mean	*0.11*	*0.18*		*0.25*	*0.55*	
LSD(5%)						
Crop	0.023**			0.068**		
Treat	Ns			0.023**		
Crop x Treat	0.065*			ns		

Root length

Root length at both flowering (7.5 vs 5.0 cm) and final harvest (15.3 vs 12.3 cm) was significantly higher in peanut than in mungbean. The growth of tap root between flowering and final harvest was 7.3 cm in mungbean and 7.8 cm in peanut. There was no significant effect of soil structure on root length.

Table 3: Mean root length (cm) and total dry matter (g/plant) for mungbean and peanut at flowering and final harvest for eight treatments (All+Whole mixing, and All are standards; All-disturbed soil (All-DS); All-organic matter (All-OM); All-rice straw (All-ST); All-lime (All-L) and All-chemical fertiliser (All-CF).

Treatment	Root length (cm)		Total Dry Matter (g/plant)	
?	Flowering	Final harvest	Flowering	Final harvest
All+Whole mixing	6.21	14.73	4.02a	10.34a
All	6.85	16.53	4.27a	10.39a
All – DS	7.03	15.33	3.11b	12.21a
All – OM	6.76	13.08	2.65bc	11.37a
All – ST	6.15	13.75	2.03c	8.37b
All – L	6.63	9.63	3.54ab	7.48bc
All – CF	6.16	13.95	1.47cd	5.22cd
Nil	4.43	13.61	0.95d	3.78d

Crop	?	?	?	?
Mungbean	5.01	12.31	2.56	6.05
Peanut	7.54	15.34	2.94	11.24
LSD(5%)	?	?	?	?
Crop	1.07**	2.38*	0.41*	1.32**
Treat	ns	Ns	0.83**	2.65**
Crop x Treat	ns	Ns	Ns	Ns

Total dry matter

Significant crop and treatment main effects existed for total dry matter at both flowering and maturity however, there was no significant ($p>0.05$) crop by treatment interaction effect. While total dry matter in peanut was only slightly higher than mungbean at flowering (2.94 vs 2.56 g), at final harvest peanut had considerably greater total dry matter than mungbean (11.24 vs 6.05 g).

At flowering stage, the total dry matter was greatly reduced from All at 4.27 g to 2.03 g for All-ST and 1.47g for All-CF, while the nil treatment produced the lowest total dry matter at 0.95 g. At flowering, All-L treatment was not significantly different from All or All+Whole mixing.

At final harvest the nil treatment produced the lowest total dry matter (3.78 g), while All-CF treatment also produced low total dry matter (5.78 g) compared with other treatments. All-DS produced the highest total dry matter at 12.21 g but this was not significantly different to All-OM (11.37 g) or the All (10.39 g) and All+ Whole mixing treatments. By final harvest both the All-ST and All-L produced significantly lower total plant dry weight compared to the All treatments.

Conclusion

Crop diversification following wet season rice is one avenue of increasing agricultural productivity in Cambodia. Lowland rice soils have numerous physical and chemical constraints to non-rice crop production. The results of this omission pot trial showed that omission of rice straw mulch and chemical fertilizer had the largest effect followed by omission of organic matter application for growth. While the importance of Lime was not evident at flowering by the final harvest total dry matter was significantly reduced with the Lime omission treatment.

The positive effect of the inclusion of chemical fertiliser is to be expected given the inherent low fertility of the Prateah Lang soil type. This suggests that farmers could increase productivity by the addition of chemical fertiliser to improve productivity. However, the adoption of chemical fertiliser may be more difficult due to accessibility and cost. Rice straw however, which is an available resource, can help maintain biomass. While omission of either lime and or disturbed soil structure reduced growth, the effect was small and not significant. The treatment effects were generally larger in mungbean than in peanut indicating the sensitivity of mungbean but the interaction effect was often not significant. Our preliminary study indicated that the All soil amendments of cow manure, chemical fertilizer, lime, rice straw mulching, and sieved soil had potential for providing an adequate supply of nutrients for mungbean and peanut growth. However, there was no apparent advantage of disturbed soil for final total dry matter, root dry weight or root length. The results suggest that without lime both root dry weight and total dry weight is reduced at final harvest suggesting pH may be a concern at the latter stages of crop growth of mungbean and peanut, while this was not evident at flowering. The cow manure application tended to reduce the total plant dry weight.

Reference

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