Crop diversification in lowland rice cropping systems in Cambodia: effect of soil type on legume production.

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Abstract

The majority of rice production in Cambodia is based on rainfed lowland cropping systems, where rice is grown over the wet season, and fields left fallow over the dry season. Improved rice production systems in Cambodia have provided opportunities for crop diversification in rainfed lowland cropping areas. We aim to develop a system based on rice production in the wet season, followed by legume crops grown in the dry season, to provide farmer income over a greater portion of the year. In 2007-08, we evaluated peanut, soybean and mungbean production on 4 soil types commonly used for lowland rice production in Cambodia. Establishment and growth of legume crops varied between varieties and sites. Poor crop establishment and growth was attributed to soil physical constraints, and compounded by differences in crop management between sites. Inherent soil acidity and poor soil structure as a result of wet cultivation for preceding rice production, impaired nutrient availability and uptake by the crop. Insect pests, diseases and weeds also contributed to reductions in yield. Water management was also a significant issue in this rice/legume rotation system. Agronomic and management strategies need to be developed to minimise these constraints. There is potential for adoption of practices such as minimum tillage, retention of crop residues, raised bed configuration, irrigation strategies, and inoculation of legume seed, to improve production in this Cambodian system. Experiments to examine the effect of these treatments on legume crop production on lowland rice soils will be implemented in the 2008-09 dry season.

Key Words

farmer income, rural food security, intensification

Introduction

Agriculture is the basis of Cambodia’s economy and society, and rainfed lowland rice is the single most important crop. It occupies about 2.24 million hectares, equivalent to 87% of the rice area , and 69% of the total cultivated area (MAFF 2008). Improving agricultural productivity has been identified as a major avenue for poverty alleviation and food security in Cambodia. There is the opportunity to increase farmer income by diversifying rice-based farming through incorporating legume crops into the system (Kirchhof et al. 2000), especially if supplementary water is available (Chan et al. 2004, Chet et al. 2008). The potential for increasing farmer income provided the impetus to examine crop diversification with lowland rice systems in Cambodia.

Traditionally, lowland rice is grown as a wet season crop, sown from May-June, and harvested in November-December, with land remaining fallow over the dry season. The modified cropping system proposes to sow legumes immediately after the rice is harvested, to maximise the use of residual soil moisture. There are a range of soil types used for rice production in Cambodia (White et al. 1997), and we aimed to identify suitable soils for peanuts, mungbean and soybean. Constraints imposed by these soils and growing conditions were also monitored. Some farming practices used in Australian may be transferable and assist in improved legume production in Cambodia. This paper presents initial results of legume crop suitability for four common rice soils in Cambodia, discussing the range of constraints, agronomic and otherwise, and suggesting future experiments to identify the best practices to address these constraints through innovative management and technologies.

Methods

Location and design

The experiments were conducted at 10 sites in Kampong Cham (KC), Kampong Thom (KT) and Takeo (TK) provinces in Cambodia. Sites were selected within these provinces on four different soil types; Prateah Lang (PL), Bakan (BK), Prey Khmer (PK) and Toul Samrong (TS). General characteristics of these soil types are provided in Table 1. An additional experiment was sown at the Cambodian Agricultural Research and Development Institute (CARDI) (11^{o}28'35''N, 104^{o}48'26''E). Experimental design was consistent between sites; randomised complete block with three replications. Variety was assessed within each site, consisting of two varieties each of; soybean (vars. DT84 and B3039), mungbean (vars. VC3541B and ATF3946) and peanut (rough and smooth shelled local varieties).

Land preparation consisted of 2-3 ploughings after the rice was harvested. Basal fertiliser of 90:30:15 kg/ha ($N:P_2O_5:K_2O$) was applied prior to planting and incorporated by cultivation. A top-dressing application of 0:30:15 kg/ha ($N:P_2O_5:K_2O$) was applied approximately 2-3 weeks after sowing. Plots were approximately 5m x 5m. Row spacing was 50cm and plant spacing within row was 20cm. Sowing was conducted with 2-4 seeds per hill and thinned to 1 per hill, and missing hills re-sown, approximately two weeks after seedling emergence. Planting dates were between December and February, coinciding with the end of the wet season. Hand-weeding was done 2-3 times during the crop cycle. Insect control and irrigation regime was at the discretion of the farmer, in conjunction with the provincial district agronomist (PDA).

Table 1. Physical and chemical characteristics of lowland rice soils in Cambodia, and the percentage of the rice area they occupy.

Soil type[a]	Area (%)	Sand (%)	Silt (%)	Clay (%)	CEC	pH (1:5 CaCl)	Organic C (g/kg)	Total N (g/kg)	Colwell P (mg/kg)
Prateah Lang[b] (Plinthustalfs)	28	50	37	13	3.71	5.0	4.3	0.2	10
Bakan (Alfison/Ultisol)	13	35	49	16	4.84	4.3	4.0	0.2	4
Prey Khmer (Psamments)	11	73	22	5	1.45	4.8	2.2	0.2	2
Toul Samroung (Vertisol/Alfisol)	10	28	29	42	16.0	4.5	11.7	1.0	7

[a]Local name according to White et al. (1997). [b]Loamy Phase. Names in parentheses refer to the *Key to Soil Taxonomy*. Adapted from CARDI (2005).

Measurements

Soil samples were taken at 0-25cm, 25-50cm and 50-75cm to assess bulk density, soil moisture, soil nutrients and soil strength on the 13th December 2007 and 10th January 2008 at the Kampong Thom / Kampong Cham and Takeo provinces respectively. Time between soil sampling and sowing varied between sites. At the majority of sites, management of the crop, and collection of data and field observations, was the responsibility of the PDA; at some sites, it was the farmer's sole responsibility. The

PDA or the farmer is then responsible for providing the data to CARDI scientists. Plant measurements consisted of emergence counts, 50% flowering, and nodulation. Observations on insect dynamics, weed spectrum and disease prevalence were recorded through the season. Amount of water applied was estimated. Yield was collected as total plot yield. Data was analysed using IRRISTAT? Combined Analysis of Variance.

Results and Discussion

Site and soil water characteristics

The proposed rotation system is based on sowing the legume following the rice crop as soon as practicable to maximise the use of residual soil moisture remaining after the wet season. Kirchhof et al. (2000) considered that legume crops following rice on clay soils could achieve acceptable yields without irrigation provided roots could access the subsoil water reserve. In this initial season, our experiments aimed to examine yield potential of legumes on different soil types, in the absence of other constraints, including water. Consequently, all sites required irrigation, due to the late sowing dates at most sites resulting in depleted soil residual moisture. Sowing date, or more specifically, the length of time between rice harvest and sowing the legume crop, has critical implications for production, related to soil drying and the resultant increase in soil strength (Kirchhof et al. 2000).

Sowing dates and length of time between rice harvest and sowing varied between sites, with resultant differences in soil profile moisture (%) at time of sowing (Table 2). Conclusions on the capacity of residual soil moisture in different soil types to grow a crop is confounded by differences in number of days from soil sampling to sowing (DTS) (7 to 73 days), and time between rice harvest and sowing (DR-S) (5 to 80 days). At some sites, such as KC BK, where rice was still to be harvested, and soil moisture values were relatively low, the profile was being rapidly depleted of moisture available for the subsequent legume crop. Using shorter season rice varieties is an option now available to Cambodian farmers, and this will provide a greater opportunity to add an additional crop to the rice farming system. Confounding the effect of irrigation and infiltration, a hard pan was found at approximately 20-30cm (values up to 8kN) at all sites, developed as a result of puddling practices in the previous rice phase. Sites varied considerably in their watering regime, ranging from 2mm/day with watering cans, to furrow irrigated weekly.

If we consider that the proposed system should be based on sowing the legumes into a full moisture profile, suggesting a criterion of sowing within two weeks of rice harvest, depending on farmer practice, then only one site, KC BK, satisfied this condition. However, soil moisture was already depleted by time of sowing. Results from this season indicate that soil moisture reserves only, may not be adequate for DS legume crop production, and that irrigation will be a significant component of this proposed system. Soil profile moisture and soil strength attributes and timing of sowing will be topics for future research.

Table 2. Soil moisture content (%) and days since rice harvest (DRH) (positive indicates that rice was still to be harvested) at time of soil sampling. Date of sowing, the number of days between soil sampling and sowing the legume crops (DTS), and number of days between rice harvest and sowing of legumes (DR-S) varied between sites.

Depth (cm)	Soil Moisture (%)									
	KC PL#	KC TS	KC BK	KT PL	KT PK	KT BK	TK PL1	TK BK	TK PL2	TK PK
0-25	na	20.9	13.9	28.7	20.5	38.5	27.5	20.9	3.6	22.7

25-50	na	40.8	18.4	34.9	33.9	38.5	25.8	20.4	26.4	15.4
50-75	na	38.8	29.2	44.6	33.5	43.4	22.0	27.6	32.2	18.4
DRH	14	+9	+9	10	7	7	25	25	60	25
Sown (DTS)	29Jan (47)	27Feb (73)	27Dec (14)	4Jan (21)	27Dec(14)	21Dec (8)	17Jan (7)	9Feb (30)	31Jan (20)	11Feb (30)
DR-S	61	64	5	31	21	15	32	55	80	55

[#]Site was saturated with standing water on the soil surface, so samples not taken.

Plant establishment

Seedling emergence is a major limitation to legume production after rice for lowland soils (Rahmianna et al. 2000). We measured plant establishment but not emergence prior to re-sowing missing hills, so values do not account for re-sown plants and early mortality at some sites. There was a significant site by variety interaction (P<0.001) for plant establishment, where most sites produced adequate crop populations (>65% mean for all varieties). Results for selected sites are presented in Table 3 (other data not available). Plant establishment varied within soil type, indicating that differences in crop management, such as watering regime and insect management, confounded the effect of soil type. For example, within the PL soil type, severe surface crusting which restricted seedling emergence was observed at some sites if the soil surface was allowed to dry out, but when soil moisture was maintained, seedling emergence was satisfactory.

Table 3. Establishment % at selected sites for 6 legume varieties.

?	Establishment (% of sown hills) at selected sites					
Variety	KC BK	KT PL	TK BK	TK PL1	TK PL2	CARDI PL
MB VC3541B	84	26	86	78	80	70
MB ATF3946	88	39	66	75	77	76
SB DT84	73	92	83	70	61	61
SB B3039	22	69	87	67	57	29
PN Smooth	93	86	75	85	86	63
PN Rough	91	83	92	80	82	63

LSD (5%)	Site x Variety: 20

In-crop Observations

Insects were a major problem, consistent with previous studies in Cambodia with dry season non-rice crops (Chan et al. 2004), especially pod borers in soybean (*Etiella zinckenella*, *Maruca testualis*) and aphids on mungbean. At one site, greater than 90% pod damage in soybeans was estimated. Weeds were also a problem, mainly volunteer rice and nutgrass. No inoculum was applied to the legume seed, and field observations indicated that although peanut produced some effective nodules, the other two legume crops produced very few or no nodules.

Yield

Yield data was not yet available. However, observations indicate that peanuts are the most promising crop across all soil types, due to very low yields of soybean from insect damage, and poor mungbean growth.

Capacity

A limited capacity and understanding of legume crop production practices by Cambodian farmers and PDAs was observed throughout the experiments. Conducting experiments on farmer's fields also posed constraints with respect to data collection and crop management for optimum yield. A significant challenge will be the extension of these improved technologies to rural Cambodia.

Conclusion

Peanuts and the Prey Khmer soil type had the least production limitations, but conclusions on differences in legume crop suitability between soil types were confounded by management differences, especially time of planting in relation to rice harvest, watering regime and insect control. However, the experiments allowed identification of a number of constraints on legume production following rice. Insect damage was a significant constraint. Water requirement was the main factor influencing crop growth, influenced by time after sowing after rice harvest, and interaction with soil type. Future research will focus on this aspect, and associated management practices for better crop establishment and water use efficiency, such as the use of raised bed configuration, minimum tillage, and retention of surface residue to ameliorate the hard-setting soil surface attributes and to maintain soil profile moisture.

Acknowledgements

The authors thank the Australian Centre for International Agricultural Research (ACIAR) for financial support, the staff at CARDI and the Provincial Department of Agriculture for their technical assistance, and provincial farmers involved in the project for their cooperation.

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