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Effects of straw mulch on mungbean yield in rice fields with strongly compacted soils

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ABSTRACT

In rice-based lowland areas in the Mekong region, the lack of full irrigation water availability for post-rice legume crops and the poor soil physical and chemical conditions are major constraints for development of sound rice/legume double cropping system. In order to improve legume productivity, use of rice straw mulch and various crop establishment methods were examined in two series of mungbean experiments in Cambodia where soils were coarse and strongly compacted. In one set of experiments conducted at four locations in the first year the effect of straw mulch, planting method (manual vs seed drill) and tillage method (conventional vs no-till) was examined. Another set of experiments were conducted in the second year at three locations with four levels of mulch under two planting densities. On average in year 1, mulching of rice straw at 1.5 t/ha increased mungbean crop establishment from 72 to 83%, reduced weed biomass from 164 to 123 kg/ha and increased yield from 228 to 332 kg/ha. Mulch was effective in conserving soil moisture, and even at maturity the mulched area had on average 1% higher soil moisture content. The amount of mulch between 1 and 2 t/ha did not show consistent effects in year 2, partly because some mulch treatments resulted in excessive soil moisture content and were not effective. Rice straw mulch had a significant effect on mungbean yield in 6 out of the 7 experiments conducted in two years, and mean yield increase was 35%. This yield advantage was attributed to better crop establishment, improved growth and reduced weed pressure, but in some cases only one or two of these factors were effective. On the other hand, planting method, tillage method and planting density had only small effects on mungbean yield in most experiments. Only in one location out of four tested, the no-till treatment produced significantly higher yield than the conventional method. Seed drill produced similar mungbean establishment and grain yield to the manual planting suggesting that the planter can be used to save the labour cost which is increasing rapidly in the Mekong region. Maximum root depth varied little with mulch or planting density, and was shallow (<20 cm) in all three locations where this character was determined. It is concluded that while rice straw mulch increased yield of mungbean following rice, the inability of mungbean roots to penetrate the hard pan is a major constraint for development of a sound rice/mungbean cropping system in the lowlands with compacted soils.

1. Introduction

Rice is the main crop for many lowland farmers in Southeast Asia. In most areas rice has been grown as monoculture for a long time. However, crop diversification is required to increase crop productivity and income for mostly subsistence farmers in the region. The rice–wheat cropping system is well established in the sub-continent, where temperature and water availability are suitable for this cropping system. In heavy soils in Indonesia and the Philippines, water holding capacity is high, and legume crops can grow well after rice harvesting using residual soil water. Crop diversification may not be easy to achieve in the Mekong region including Northeast Thailand, Laos and Cambodia where availability of irrigation water is limited and soils tend to be sandier with low water holding capacity and low nutrient availability (Pheav et al., 2005; White et al., 1997; Seng et al., 2001, 2008). The puddled lowland soils also tend to be high in soil strength with a relatively shallow hardpan which would affect growth of post-rice crops (Fyfield et al., 1990; So and Ringrose-Voase, 2000).

Legume crops can be useful addition in rice-based rainfed lowland cropping systems with their ability to provide fixed N. Green manure crops such as *Sesbania rostrata* can contribute to improved N availability to the following rice crop in sandy soils of the Mekong region (Herrera et al., 1997). Groundnut residues of 5 t/ha increased rice N uptake from 39 to 51 kg/ha and rice grain yield from 2.8 to 3.1 t/ha in Kalasin province in NE Thailand (Kaewpradit et al.,

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2009). In another study in NE Thailand, Toomsan et al. (1995) found that when stover was returned to the field, N_2-fixation of groundnut contributed 13–100 kg N/ha to the subsequent rice crop and there was a 12–26% increase in rice yield. However, this was not the case with soybean which had high harvest index, and most fixed N was removed with harvesting of the grain. Mungbean is often considered to be suitable as a post-rice crop in the lowlands, mainly because of its short crop duration which fits well in the cropping system where irrigation water is limited or temperature becomes very high in late dry season. Previous attempts to develop rice/mungbean double cropping in Cambodia have had limited success as often mungbean establishment was poor and consequently poor crop growth and low yield (Chan et al., 2004; Ouk et al., 2007). In areas where water availability is limited and soil temperature is high, straw mulch may assist mungbean growth and yield, as found in India (Chaudhary et al., 1985). Verma and Kohnke (1951) have shown the potential beneficial effects of rice straw mulch to reduce soil temperature, soil surface crusting and evaporation of moisture. Van Den Bergh and Lestari (2001) studying the improvement of local cultivation of soybean with 86 farmers in Indonesia, found that the use of rice straw, spread over plots to a depth of 4–10 cm, increased soybean yields across sites by 41%. They concluded that the beneficial effect of rice straw mulch depended on the degree of moisture stress and the physical properties of the soil. In sandy textured lowland soils in the Mekong region, rice straw mulch with legume residue may also help N availability during subsequent rice growth, as was found in rice–groundnut rotation system in NE Thailand (Kaewpradit et al., 2009). Rice straw mulch may tie up soil N and promote N fixation by the legume crop. Thus, rice straw mulch on non-rice crop in lowlands improves water, soil and temperature environments which results in (i) increased establishment, (ii) improved growth of non-rice crops, and (iii) reduced weed growth directly or indirectly through improved crop growth, and these all contribute to increased crop yield. In addition to the positive effect of mulch on the crop, this practice of using crop residues as mulch contributed towards maintenance of soil fertility over a long period of time (Martin and Belfield, 2007).

Ploughing soils before planting is a common practice in the lowlands in the region, but this promotes soil evaporation and soil stored water is reduced. Another method of conserving soil water is the use of no-till cropping. The potential use of no-till establishment was examined in the present work, together with the use of seed drill. Increasing labour cost in the region has meant that any labour saving method is worth consideration.

The objective of the study reported here is to examine the effect of the use of rice straw mulch and various crop establishment methods on growth of mungbean crops planted after harvesting rice in lowlands in the Mekong region where hard pan development is common and can cause constraints to post-rice crops. Of particular interest is to attribute the magnitude of yield increase as a result of mulch application to improved crop establishment, better growth and better control of weeds.

2. Materials and methods

Two mungbean experiments were conducted in lowland conditions after harvesting rice at the end of the wet season. The mungbean variety used was CARDI Chhey in all locations for the two years.

2.1. Effect of mulch, planting method and tillage method (Experiment 1)

Experiment 1 was conducted from December 2008 to April 2009 at four locations (Takeo, Kampong Cham, Kampong Thom and Preah Vihear provinces) in Cambodia. The soil types of the experimental area were Bakan (Alfisol/Ultisol), Prateah Lang (Plinthustalfs), Prey Khmer (Psamments) and Prateah Lang soil types, respectively. The chemical/physical properties of these soils are well described in White et al. (1997) and Bell and Seng (2004). The Preah Vihear site was newly cleared while other locations had a long history of rice growing under lowland conditions. Each trial tested two tillage treatments under two planting methods with mulch and no mulch applications. A split–split plot design was used in the trials, the tillage treatment being assigned to the main plot, the planting method sub plot and the mulch application sub–sub plot. There were three replications and each plot size was 4 m × 3 m.

The tillage treatments consisted of no-till and conventional tillage. The no-till plots were not ploughed and rice stubble was retained. Glyphosate was applied at the rate of 2.5 L ha^{-1} at 6–14 days before planting. The conventional tillage plots were ploughed twice using a tractor with seven disc plough, the plough depth ranging from 15 to 20 cm. The first plough was immediately after harvesting rice and second plough one day before planting mungbean. The fertilizer rate was 90N–60P_2O_5–30K_2O kg/ha (urea 124 kg/ha, DAP 95 kg/ha and KCl 37 kg/ha) for all trials (locations) and was applied during land preparation and as top dressing. High N fertilizer rate was used in the experiment to ensure N was not limiting the mungbean growth as no healthy nodules were observed on mungbean in an earlier investigation conducted under similar conditions to the present work. Fertilizer was applied by spreading over the surface of no-tillage plots and incorporating it with the last plough in the conventional tillage plots. There were no furrows in this experiment, and the land level was kept flat throughout the experiment. To avoid development of plant water stress, irrigation water was applied by hand using buckets whenever soil surface became dry.

The planting methods tested were (a) manual planting (dibbling) and (b) seed drill (machine). In the manual planting, 3 cm deep holes were made using a dibbling stick and three seeds were placed in each hole and the soil was pressed firmly around the seed with the feet. The row spacing was 40 cm and hill spacing was 30 cm. Both manual and seed drill plantings used a seeding rate equivalent to 20 kg/ha. The seed drill was followed by press wheel.

In the mulch application treatment, rice straw was collected from nearby paddies, and applied at the time of mungbean planting at a rate of 1500 kg/ha which created about 1 cm thick mulch on the soil surface. Gravimetric soil moisture content (0–20 cm) was determined at planting and post harvest in three replications. Rainfall, soil temperature and atmospheric humidity were determined daily. Percentage of crop establishment was measured from three 0.5 m × 0.5 m areas per plot at 15–22 days after planting (DAP). Weeds were sampled from 6 random positions using a quadrant frame (0.5 m × 0.5 m) in each plot. Weed samples were taken on 15–22 DAP and again 43–48 DAP. Weeds were oven dried and dry weight determined and combined dry weight from the two sampling times was used to show the magnitude of weed infestation. Mungbean grain was harvested three times in each trial.

Statistical analysis was conducted using Genstat version 13. Single site (location) analysis was followed by combined analysis across locations, with treatment main effects and interaction effects determined.

2.2. Effect of mulch and planting density (Experiment 2)

Experiment 2 was conducted after harvesting rice from December 2009 to April 2010 at three locations (Takeo and Kampong Thom provinces and in Cambodian Agriculture and Research Development Institute (CARDI) in Phnom Penh). The two locations in Takeo and Kampong Thom were different from those used in year 1. The soil type was Prateah Lang at all the experimental sites. The Kam-