Research article

Soil Amendments for Maize Cultivation by Crop Rotations in Upland Cropping Systems of Southeast Cambodia

TARA PIN*
Faculty of Agriculture, Chea Sim University of Kamchaymear, Cambodia
Email: pintara30@gmail.com

KONGKEA PHAN
Faculty of Science and Technology, International University, Phnom Penh, Cambodia

VANNARO PIN
Faculty of Agriculture, Chea Sim University of Kamchaymear, Cambodia

OEUN HORN
Faculty of Agriculture, Chea Sim University of Kamchaymear, Cambodia

JOHN M. SCHILLER
School of Agriculture and Food Sciences, University of Queensland, Australia

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Abstract A study was made of the importance of crop rotations on the growth and yield of maize in upland cropping systems of Cambodia. Maize (MZ) was grown continuously and in two-year rotations with cassava (CS), soybean (SB), mung bean (MB) and peanut (PN). Six different rotations T1, T2, T3, T4, T5 and T6 were designed and studied in the upland cropping systems in the provinces of Prey Veng and Svay Rieng in southeastern Cambodia. Mono-cropping with maize (T0) was used as the control treatment in the study. The study was undertaken in the period 2013 to 2015. The field experiments revealed an increase in crop yields in the order of T1 > T2 > T3 > T5 > T6. There was no significant difference in crop yield between T4 and the control (T0) treatment. The analysis of soils data revealed that there were no significant differences in soil nitrogen and phosphate levels pre-treatment and post–treatment in each of the rotations (paired samples t test, $p > 0.05$). However, post-treatment potassium levels were significantly lower than the pre-treatment levels in all cropping rotations ($p < 0.05$) except T0. The results of the study suggest that the maize-legume rotation is the most promising crop rotation for yield improvement in the upland cropping systems in southeast Cambodia.

Keywords maize, crop rotation, upland cropping system, Cambodia

INTRODUCTION

It is Cambodian government policy to encourage crop diversification (i.e. to grow cash crops other than rice), especially in non-rice upland agro-ecological systems (Chan et al, 2009). Cambodian farmers, extension workers and researchers, are less familiar with crop rotations than with mono-cropping, as the focus of the research has been on cassava cultivation for many years on the same land. Cassava production is also perceived to degrade soil fertility. This is also a major contributing factor to the relatively low cassava yields in areas where cassava has been cropped over many years. Maintaining soil fertility is one of the main challenges in agricultural production systems in Cambodia. Intercropping is one of the options available for more sustainable agricultural production systems.

Other benefits of intercropping include, spreading of risk (relative to single cropping), improved weed management, and reduced incidence of insect pest and disease damage. The Government of the 3rd Constitution has adopted a development strategy which is partly based on crop intensification and diversification (MAFF, 2007). Most farmers in the provinces of Prey Veng and Svay Rieng have tried to intensify agricultural production through mono-cropping of cassava, reflecting the high demand for this crop in commercial markets. However, this cropping intensification has been done with little knowledge of procedures or technologies for maintaining soil fertility.

Soil fertility (and therefore crop yields) has shown a significant decline in areas with a long history of cassava cropping, as smallholder producers are unable to afford commercial fertilizers to replace the nutrients removed by successive cassava crops. To date, mono crops in Cambodia are generally low yielding, with little knowledge and financial information available on the best management practices for soil fertility maintenance in mono cropping systems, and often unsuitable are being grown. Attention to the agronomic aspects of rotation crops, especially soybean and mungbean is required. Growers need agronomic advice which will reduce the risk of degradation in soil fertility (Chan et al., 2009). To enhance food security and sustainable livelihoods, improvements are needed in agricultural techniques for enhancing production in upland rural areas of Prey Veng and Svay Rieng Provinces of Cambodia. A combination of poor soils and a dependence on non-irrigated agricultural production are the basis of low agricultural production and high levels of poverty in Prey Veng and Svay Rieng Provinces.

OBJECTIVE

The goal of this project was to use an on-farm, farmer participatory approach to study a range of potential agricultural technologies for enhancing and sustaining agricultural production and incomes in Prey Veng and Svay Rieng Provinces. The main objectives of the study were to: (1) determine the promising crop rotation options for improving fertility and food crop production of the Prey Khmer soil group in upland cropping system of Prey Veng and Svay Rieng provinces; and (2) investigate the changes in soil chemical and physical properties after crop rotations.

METHODOLOGY

The study was carried out in Prey Veng and Svay Rieng provinces which are located in the Southeastern part of Cambodia (Fig. 1). The continuous mono-cropping particularly with cassava in these upland areas has led to a progressive decline in soil fertility. There is an urgent need to identify alternative agricultural production options capable of economically improving both the soils and production, while the same time improving incomes of rural households which are almost 100% dependent on agriculture.

Six different treatments (combinations of maize (MZ), cassava (CS), mungbean (MB), soybean (SB) and peanut (PN)) T1 (SB-MZ-MB-MZ), T2 (PN-MZ-SB-MZ), T3 (MB-MZ-PN-MZ), T4 (CS-CS-CS-MZ), T5 (CS-MB-PN-MZ) and T6 (CS-SB-PN-MZ) were designed to investigate on the growth performance and crop yield of maize in eight basic production systems (7m × 10m) in the study areas of Prey Veng (n = 4) and Svay Rieng (n = 4) provinces. The mono-cropping of maize was used as a control in the present study. Field trials were conducted in the field of farmers and carried out at appropriate times throughout the growing seasons. The Proposed cropping treatments and timetable of cropping activities are summarized in Table 1. The plant height (cm), the number of ear per plant, ear length (cm), ear size (cm), weight (g) per ear and maize yield (dwt) per hectare (t/h) were measured before the next cycle of ration. Concurrently, soil samples were collected at depth of 10-30cm before and after each treatment to determine soil properties and measure the changes in their total C, organic C, N, P_2O_5, Ca, Mg, Na, K and exchangeable acidity (pH_{KCl}) and actual acidity (pH_{H2O}).

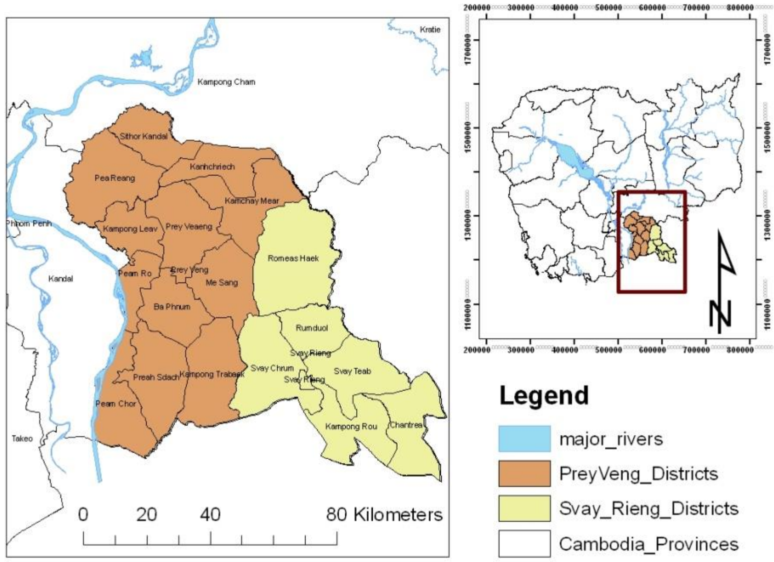

Fig. 1 Map of the study areas

Table 1 Summary of crop rotations in the upland cropping system in Prey Veng and Svay Rieng provinces

Treatment	2013		2014		2015	
	EWS	LWS	EWS	LWS	EWS	LWS
T0	-	MZ+F	MZ+F	MZ+F	MZ+F	-
T1	-	SB+F	MZ+F	MB+F	MZ+F	-
T2	-	PN+F	MZ+F	SB+F	MZ+F	-
T3	-	MB+F	MZ+F	PN+F	MZ+F	-
T4	-	CS+F	CS+F	CS+F	MZ+F	-
T5	-	CS+F	MB+F	PN+F	MZ+F	-
T6	-	CS+F	SB+F	PN+F	MZ+F	-

EWS, early wet season; LWS, late wet season; MZ, maize; SB, soybean; MB, mungbean; CS, cassava; PN, peanut; +F, fertilizer application

All statistical analyses were performed using SPSS for Windows (Version 16.0). The t-test was applied to verify significant differences in the growth performance and crop yield between the six treatment methods with a control and differences in the growth performance and production yield between the two study areas. One way ANOVA was applied to verify the differences in the growth performance and crop yields among the six rotation designs. Paired samples *t* test was applied to verify the difference of soil physical and chemical properties before and after treatment. The significance was considered in a circumstance where $p < 0.05$.

RESULTS AND DISCUSSION

Plant height (cm), number of ear per plant, and yield per hectare (t/h) of maize after crop rotation are presented in Table 2. A comparison revealed that there were no significant differences in plant height of control (T0) with each treatment (t-test, $p > 0.05$). However, there was a significant difference in number of ear per plant among all treatments (One-way ANOVA, $F(6, 49) = 12.11$, $p < 0.01$). Post-hoc Tukey HSD tests showed that there were significant differences in number of ear per plant between T0 and T1, T2, T3 and T5 ($p < 0.05$), but T4 and T6 were not significant different in number of ear per plant with T0 ($p > 0.05$). A statistically significant difference was found among all treatments on ear length, $F(6, 49) = 11.45$, $p < 0.01$. The ear length of T0 was significantly shorter than that of T1, T2 and T3 ($p < 0.05$) using Games-Howell post-hoc test. Likewise, ear size were statistically different among all treatments (One-way ANOVA, $F(6, 49) = 11.42$, $p < 0.01$). Ear size of T1, T2 and T3 were statistically bigger than that of the control using Tukey HSD post doc test. A statistically significant difference was found among all treatments on weight of ear, $F(6, 49) = 8.50$, $p < 0.01$.

Table 2 Summary of growth performance and crop yield of maize crop rotation in the upland cropping systems in Prey Veng and Svay Rieng provinces

Treatment	Statistics	Plant height (cm)	Number of ear/ plant	Yield (t/h)
T0 (n = 8)	Mean	111.9	1.1	4.9
	S.D	27	0.1	0.3
T1 (n = 8)	Mean	138.4	1.5	7.9
	S.D	26.4	0.1	1.1
T2 (n = 8)	Mean	125.8	1.4	6.9
	S.D	18.5	0.2	0.7
T3 (n = 8)	Mean	135.1	1.4	6.5
	S.D	22.2	0.2	0.9
T4 (n = 8)	Mean	112.6	1.1	4.9
	S.D	18	0.2	0.8
T5 (n = 8)	Mean	109.3	1.4	5.9
	S.D	16.7	0.1	0.7
T6 (n = 8)	Mean	122.9	1.2	5.8
	S.D	21.4	0.1	0.4

S.D, standard deviation; Yield is on 100% dry weight

Weight of ear of T1, T2 and T3 were significantly heavier than that of T0 using Games-Howell post-hoc test. Analytical results revealed that there were statistically significant differences in crop yield among all treatments (One-way ANOVA, $p < 0.05$). Further comparison indicated that crop yield of treatment 1 (T1) is statistically significant higher than that of the control (T0) (t-test, $p < 0.05$). Likewise, the crop yields of T2, T3, T5 and T6 are statistically significant higher than that of the control (t-test, $p < 0.05$). It seems like the plant height is associated with crop yield without consideration of rotation. Concurrently, it is more likely that crop yield is associated with number of ear per plant, ear length, ear size and weight of ear. The present study showed that maize growth was better in the crop rotation system than mono-cultured soil (control). This result is consistent with the results of an earlier study by Horst and Härdter (1994) which found that in pot experiments, maize growth was much better in the soil from the crop rotation than from the mono-cropping plots. Crop yield of the present study was increased through crop rotation which is consistent to a statement by Honeycutt et al., (1995).

The physical and chemical properties of soils before and after treatments are presented in Table 3. Soil before crop rotation composed of sand, silt and clay of 66%, 26% and 8%, respectively. When plotting the percentage of all particles in the triangle diagram, the texture of soil was found to be sandy loam. However, the soil texture was not altered after crop rotation. In general, the management practices do not alter the textural class of a soil on a field scale. Changing the texture of a certain soil would require mixing it with another soil material of a different textural class. For example, the incorporation of large quantities of sand to change the physical properties of a clayey soil for use in greenhouse pots would be considered to change the soil texture (Brady and Weil, 2007).

Table 3 Mean values of the chemical and physical properties of soils before (n = 8) and after (n = 8) treatment

Treatment	Org C	N	P_2O_5	Ca	Mg	Na	K	pH
			Pre-treatment					
T0	2.4	1.18	188.69	2.59	1.68	0.18	0.25	4.6
T1	2.4	1.18	188.69	2.59	1.68	0.18	0.25	4.6
T2	2.4	1.18	188.69	2.59	1.68	0.18	0.25	4.6
T3	2.4	1.18	188.69	2.59	1.68	0.18	0.25	4.6
T4	2.4	1.18	188.69	2.59	1.68	0.18	0.25	4.6
T5	2.4	1.18	188.69	2.59	1.68	0.18	0.25	4.6
T6	2.4	1.18	188.69	2.59	1.68	0.18	0.25	4.6
			Post-treatment					
T0	1.81	1.1	178	3.08	1.27	0.12	0.17	4.71
T1	2.03	1.22	152.13	2.99	1.33	0.12	0.15	4.82
T2	2.11	1.4	148.25	3.23	1.31	0.11	0.14	4.98
T3	1.77	1.14	177.63	3.08	1.35	0.09	0.16	4.89
T4	2.15	1.28	161.5	3.21	1.33	0.11	0.17	5.08
T5	2.05	1.24	162.5	3.17	1.34	0.1	0.14	4.96
T6	1.89	1.1	167.25	3.31	1.41	0.09	0.16	4.82

Org C, N, P_2O_5, Ca, Mg, Na, K in mg kg^{-1}

A comparison indicated that the total carbon of the post-treatment and pre-treatment in each rotation were not significantly different (Paired samples *t* test, $p > 0.05$), except T2 that total carbon of post-treatment was significantly higher than that of pre-treatment ($t = -2.59$, $p = 0.036$). Likewise, there were not significant differences in organic carbon between pre-treatment and post-treatment of most rotation (Paired samples *t* test, $p > 0.05$), except T0 and T4. Further analysis revealed that there were not significant differences in total nitrogen and phosphate between pre-treatment and post –treatment in each rotation (Paired samples *t* test, $p > 0.05$). A paired samples *t* test indicated that K of post-treatment were significant lower than that of pre-treatment in each rotation ($p < 0.05$), except T0. However, Ca of post-treatment was significant higher than that of pre-treatment in each treatment (Paired samples *t* test, $p < 0.05$), except T2 and T5. Analytical results revealed that Mg of the post-treatment were significantly lower than that of pre-treatment in all treatment (Paired samples t test, $p < 0.05$). However, Na of the post-treatments was not significantly lower than that of the pre-treatment, except T3 and T6 (Figure 18). The exchangeable pH of pre-treatment were significantly lower than that of post-treatment of T1, T2 and T4 (Paired samples t test, $p < 0.05$); however, there were not significant differences in the exchangeable pH of T0, T3, T5 and T6 (Paired samples t test, $p > 0.05$). Concurrently, a comparison showed that the actual pH of pre-treatment were not significantly different from that of post-treatment of T0, T1, T4, T5 and T6 (Paired samples t test, $p < 0.05$) while marginal difference was found in T2 and T3. A study of field crop productivity in relation soil properties in Basaltic soils of Eastern Cambodia found that drought, soil acidity, inadequate N fertilizer were the main factors accounting for the unreliable performance of maize (Seng et ., 2011).

CONCLUSION

Crop rotation for maize production was successfully implemented in the upland cropping system in Prey Veng and Svay Rieng provinces in Cambodia. Experimental results revealed that crop yield increased in the order of T1 > T2 > T3 > T5 > T6. Although post-treatment K was significantly lower than that of pre-treatment, N and P_2O_5 were not significantly different before and after the treatment. This study suggested that the rotation of soybean-maize-mungbean-maize T1 (SB-MZ-MB-MZ) was the most promising crop rotation to increase maize yield in the upland cropping system of Cambodia.

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