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Economic viability of including crude humic substances, chicken litter biochar, and clinoptilolite zeolite in rice cultivation on acid soils

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Abstract

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Chemical fertilizers are important for improving crop yield. However, fertilizers cost, concerns for sustainable soil and crop productivity, ecological stability, and economic viability have been expressed. A field study was carried out on Bekenu Series (*Typic Paleudults)* to determine the effects of (i) using conventional fertilizers, crude humic substances, chicken litter biochar, and clinoptilolite zeolite in rice cultivation on acid soils, and (ii) the economic viability of including the soil amendments in rice cultivation. Results revealed that long-term cultivation of rice based on conventional method is not economically sustainable. Regardless of cropping cycle, crude humic substances were economically viable. Farmers who include chicken litter biochar or clinoptilolite zeolite in their rice cultivation can breakeven in the second and third field planting cycles. Incorporating crude humic substances is the most economical practice in rice cultivation followed by chicken littler biochar or clinoptilolite zeolite.

Keywords: acid soils; biochar; clinoptilolite zeolite; economic viability; humic substances
Abbreviations: BCR – benefit cost ratio, NR – net revenue, NPV – net present value, TC – total cost, TR – total revenue

Introduction

Economic viability occurs when farm income is maximized from proper use of nutrient inputs including fertilizers use, but it is not easily predicted or always achieved because future yield increases, fertilizer costs, and crop prices are not known in advance of the growing season (Tilman et al., 2002). Economic viability is any production that can financially support itself. Using farming as an example, economic viability refers to the ability of a farm to return investment. However, it is important to achieve economic viability together with environmental efficiency. Environmental efficiency is site-specific and can only be determined by studying local targets vulnerable to nutrient impact (Ghosh et al., 2015). Total production costs and revenue are important factors which dominate the decision-making process of farmers. Total production cost means expenses incurred to produce a particular amount of a product for a particular period. An important economic consideration is what cost (price) to use in valuing resources used in production process. Farmers can price some resources such as seeds, fertilizers, lime, fuel, and hired labour based on current market prices (Lessley et al., 1991).

Total revenue refers to the total receipts from sales of a given quantity of goods or services. It is the total income of a business and it is calculated by multiplying the quantity of goods sold by the price of the goods (Aaron, 2015). Apart from total production and revenue, benefit cost ratio (BCR) analysis is also an important tool to determine economic viability of farming. According to Mehmood et al. (2011), BCR is the ratio of net value of crop produce after deducting cost of different inputs. It indicates the rate of net returns from the use of an input (Mehmood et al., 2011). To achieve high BCR is a challenge as most slow-release fertilizers are more expensive than water-soluble fertilizers. Slow release fertilizers or technologically advanced systems such as precision farming are too expensive for many farmers in developing countries (Singh, 2002). Because of escalating costs of inorganic fertilizers, use efficiency in field plants should be significantly improved to reduce cost of production so as to enable greater profit for resource-poor farmers.

Rice is one of the widely grown staple foods in the world. It is a very important food source in Asia including Malaysia. Global rice production is inadequate such that concerns for rice security have emerged. This pressing issue calls for improvement in the existing rice production particularly in terms of efficient use of chemical fertilizers and good maintenance of soil productivity. To obtain profitable rice yield, farmers tend to apply higher amounts of chemical fertilizers. This approach is not sustainable as excessive use of chemical fertilizers in particular has been implicated in the environmental pollution (Savci, 2012). For example, chemical fertilizers in lowland rice cultivation are easily lost through ammonia volatilization and leaching (Sharma et al., 1989; Zhengping et al., 1991; Fageria and Baligar, 2003). Moreover, excessive or unbalanced use of chemical fertilizers especially nitrogen and phosphorus based fertilizers causes eutrophication of a water bodies. Thus, application of soil amendments in lowland rice cultivation to retain and release nutrients timely for optimum plant uptake is essential. For example, crude humic substances, chicken litter biochar, and clinoptilolite zeolite can be used as amendments to control nutrients availability in soils as these amendments have high affinity for nutrients due to their high cation and anion exchange properties (Clough et al., 2013; Aainaa et al., 2014; Ghezzehei et al., 2014; Ch'ng et al., 2016). In addition, the higher organic matter contents of the crude humic substances and chicken litter biochar could increase soil organic matter and total organic carbon contents in acid soils such as Alfisols, Ultisols, Entisols, Inceptisols, and Oxisols, which are commonly used for rice cultivation although they are lower in organic matter (Fageria and Baligar, 2003). Furthermore, the basic nature of crude humic substances (pH 7.9), chicken litter biochar (pH 9.5), and clinoptilolite zeolite (pH 8.2) could increase pH of the aforestated acid soils and their nutrients availability, as nutrients availability is related to soil pH (Havlin et al., 1999).

The nutrients in crude humic substances, chicken litter biochar, and clinoptilolite zeolite could also provide additional nutrients to improve crop yield and soil quality. The ability of amendments to reduce ammonia volatilization, improve nutrient availability, N, P and K adsorption-desorption, and pH buffering capacity suggests that incorporating these organic amendments in rice cultivation could reduce chemical fertilizers use (Palanivell et al., 2015). Furthermore, increase rice yield due to organic amendment application (crude humic substances, chicken litter biochar, and clinoptilolite zeolite) and the minimal use of chemical fertilizers due to nutrients carryover or residual effects could increase rice farmers' revenue (Palanivell et al., 2015). Inclusion of high pH amendments such as crude humic substances, chicken litter biochar, and clinoptilolite zeolite will eliminate liming and the cost of liming acid soils, thus reducing production cost. To this end, cost-benefit analysis needs to be carried out to determine if the new approaches are economically viable or not. The objectives of this study were to determine the effects of (i) using conventional fertilizers, crude humic substances, chicken litter biochar, and clinoptilolite zeolite in rice cultivation on acid soils, and (ii) the economic viability of including the soil amendments in rice cultivation.

Material and Methods

Description of study area

Three field trials were conducted at the Long-Term Research Grant Scheme (LRGS) rice plot 1 (latitude 3° 12' 52.8" N and longitude 113° 5' 38.8" E) of University Putra Malaysia Bintulu Sarawak Campus. Rice variety of MR219 was used in this study as a test crop. The field trials were carried out from March 2013 to May 2014. The experimental design used was randomized complete block design (RCBD) with three replications (blocks). The total experimental area was 20×15 m. The amounts of crude humic substances, chicken litter biochar, and clinoptilolite zeolite used in the first field trial were derived from our previous pot studies (Palanivell et al., 2015), where 5, 15, and 15 t ha^{-1} respectively, which are equivalent to 2, 6, and 6 kg $plot^{-1}$ (scaled down based on planting density of 250,000 hills ha^{-1}) were used. It should be noted that hill in this study refers to a heap or mound of plants consisting of 3 plants per hill in plot with a planting distance of 20 cm × 20 cm (Bozorgi et al., 2011). The second field trial was conducted in the same plots after the first field trial. The amounts of crude humic substances (1.67 t ha^{-1}), chicken litter biochar (5 t ha^{-1}), and clinoptilolite zeolite (5 t ha^{-1}) used in the second field trial were reduced by 67% of the first trial. The amounts of the amendments used in the second field trial were 0.67, 2, and 2 kg $plot^{-1}$. Fertilization in the second field trial was done based on nutrient deficiency symptoms. Therefore, the nutrients were applied when necessary.

The fertilization schedules for first, second, and third field trials are summarized in Tables 1, 2, and 3, respectively. Complete fertilization in this study refers to 130.97 g urea + 139.17 g Egypt rock phosphate (ERP) + 87.32 g muriate of potash (MOP) + 16.45 g kieserite ($MgSO_4{\cdot}H_2O$) + 53.00 g chelated ZnCoBor per plot. The amounts of the fertilizers used were scaled down based on rice plant density for 100 rice plant hills per plot. The fertilizer rates (151 kg ha^{-1} N, 97.8 kg ha^{-1} P_2O_5, 130 kg ha^{-1} K_2O, 7.6 kg ha^{-1} MgO) were

Table 1. Fertilization schedule for first field trial

Days after transplanting (DATP)	Urea	ERP	MOP	Kieserite	ZnCoBor
	(g $plot^{-1}$)				
11 DATP	54.57	79.39	23.90	–	–
31 DATP	40.00	–	23.92	5.75	53.00
47 and 66 DATP	18.20	29.89	19.75	5.35	–

ERP – Egypt rock phosphate; MOP – muriate of potash

Table 2. Fertilization schedule for second field trial

Complete normal fertilization (T1)					
Days after transplanting (DATP)	Urea	ERP	MOP	Kieserite	ZnCoBor
	(g $plot^{-1}$)				
10 DATP	54.57	79.39	23.90	–	–
29 DATP	40.00	–	23.92	5.75	53.00
45 and 61 DATP	18.20	29.89	19.75	5.35	–
63% of normal fertilization (T2 and T3)					
Days after transplanting (DATP)	Urea	ERP	MOP	Kieserite	ZnCoBor
	(g $plot^{-1}$)				
10 DATP	Skipped				
29 DATP	40.00	–	23.92	5.75	53.00
45 and 61 DATP	18.20	29.89	19.75	5.35	–
34.3% of normal fertilization (T4)					
Days after transplanting (DATP)	Urea	ERP	MOP	Kieserite	ZnCoBor
	(g $plot^{-1}$)				
10 DATP	Skipped				
29 DATP	Skipped				
45 and 61 DATP	18.20	29.89	19.75	5.35	–

ERP – Egypt rock phosphate; MOP – muriate of potash

based on that recommended for cv. MR219 by Muda Agricultural Development Authority, Malaysia (2014). Micronutrients (2.3 kg ha^{-1} B, 4 kg ha^{-1} Cu, and 4 kg ha^{-1} Zn) were applied based on the recommendation of Liew et al. (2010). The treatments evaluated in the first, second, and third cycle field studies are shown in Table 4. The rice plants were harvested at different maturity days due to carryover effect of the amendments on grain ripening. Culm height and number of panicles were measured on the day of harvest. Aboveground biomass was harvested to determine dry matter yield and nutrient contents. Ten panicles were randomly collected from each experimental plot for grain filling, spikelets per panicle, and yield determination.

The cost of labor for each field trial was based on typical operation costs used in rice fields of Malaysia. The air pollution penalty of RM 500,000.00 by the Malaysian government (Environmental Quality Act 1974, amended in 2001) was used as the cost of pollution associated with burning residue after harvest. This residue management practice common for conventional method of cultivating rice (T1). The field materials (seeds, lime, fertilizers, herbicide, insecticides, and amendments) prices were based on the current market and farm gate prices. However, the chicken litter biochar price was based on the average market price (Kulyk, 2012). The cost of land rental was not imposed in this study

Table 3. Fertilization schedule for third field trial

Normal fertilization (T2)		
Days after transplanting (DATP)	Urea	ERP
	(g $plot^{-1}$)	
10 DATP	54.57	79.39
30 DATP	40.00	Skipped
45 and 57 DATP	18.20	29.89
Eighteen percent of normal fertilization for T3 and T8 plots		
Days after transplanting (DATP)	Urea	ERP
	(g $plot^{-1}$)	
10 DATP	Skipped	
30 DATP	40.00	Skipped
45 and 57 DATP	18.20	Skipped
Four percent of normal fertilization for T11 plots		
Days after transplanting (DATP)	Urea	ERP
	(g $plot^{-1}$)	
10 DATP	Skipped	
29 DATP	Skipped	
45 DATP	Skipped	
57 DATP	18.20	Skipped

ERP – Egypt rock phosphate; MOP – muriate of potash; T3 – plots had been applied with crude humic substances in the first and second planting cycles; T8 – plots had been applied with chicken litter biochar in the first and second planting cycles; T11 – plots had been applied with clinoptilolite in the first and second planting cycles

Table 4. Treatments evaluated in first, second and third field trials

Treatment	First field trial		Second field trial		Third field trial	
	Fertilizer	Amendment	Fertilizer	Amendment	Fertilizer	Amendment
T1	100%	na	100%	na	100%	na
T2	100%	5 t ha^{-1} rice straw compost + 0.5 t ha^{-1} sawdust ash	63%	1.67 t ha^{-1} rice straw compost + 167 kg ha^{-1} sawdust ash	18%	na
T3	100%	15 t ha^{-1} chicken litter biochar	63%	5 t ha^{-1} chicken litter biochar	18%	na
T4	100%	15 t ha^{-1} clinoptilolite zeolite	34.3%	5 t ha^{-1} clinoptilolite zeolite	4%	na

na: not applied

because most of the rice farmers cultivate on their own land. Miscellaneous cost was calculated as 5% of the total production cost (operating expenses and field material costs).

The revenue from rice yield was calculated by multiplying rice yield (t ha^{-1}) with farm-gate price (RM 1,200.00 t^{-1}). The Malaysian government provides additional incentive for every 1 metric tonne increase in rice yield compared with usual yield per hectare (Ibrahim and Siwar, 2012). Net revenue (NR) was calculated as the difference between the total revenue and total cost. Benefit-cost ratio (BCR) was calculated using the method of Nwaobiala and Adesope (2013) whereas, net present value (NPV) was determined as described by Ingabire et al. (2013):

$$\text{Benefit – cost ratio (BCR)} = \frac{TC}{TR} \quad [1]$$

$$\text{Net present value (NPV)} = \sum_{t=1}^{n} \frac{(TR - TC)_t}{(1 + r)^t} \quad [2]$$

where,

TC = total cost, TR = total revenue, and r = discount rate of rice field for per cycle (t). If NR or NPV > 0, then the total revenue is greater than the total cost, if NR or NPV = 0, than the total revenue is equal to the total cost, and if the NR or NPV < 0, than the total revenue is less than the total cost. In this study, NR and NPV are measured in Malaysian Ringgit (RM) and is based on one hectare. If BCR > 1, then the total revenue is greater than the total cost, if BCR = 1, than the gross revenue is equal to the total cost, and if the BCR < 1, than the gross revenue is less than the total cost.

Results and Discussion

Regardless of cultivation method, the costs and revenues in the first, second, and third trials are shown in Tables 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16. Table 17 summarizes the benefit-cost ratio (BCR) and net present value (NPV) of the different rice cultivation methods for three planting cycles. Liming cost was not imposed in T2, T3, and T4 because the amendments in those treatments were higher in pH (Palanivell et al., 2015), thus, they can serve as alternative of commercial lime. Irrespective of rice cultivation method, the total cost was reduced from the first trial to the third trial because of reduction in the costs of harvest, transportation, fertilizers, and amendments. The conventional rice cultivation (T1) was profitable in the first and second field trials however, there was a loss in the third field trial due to decrease in rice yield (Tables 5, 9, and 13). This suggests that the conventional way of cultivating rice may not be economically sustainable.

In the first trial, the relatively higher rice yield associated with T1 as compared to the national (Malaysia) average yield (4 to 5 t ha^{-1}) (Ministry of Agriculture and Agro-Based Industry, Malaysia, 2014) was due to the native fertility of the newly cultivated land. Continued application of chemical fertilizers reduces soil productivity (Zhang et al., 2010; Lal, 2015). For every RM 1 spent in adopting the conventional method (T1), RM 1.28, RM 1.16, and RM 0.73 were gained in return in first, second, and third field trials, respectively (Table 17). In terms of net present value, the conventional rice cultivation method is economically viable in the first and second field trials, but, not economical in the third field trial due to economic loss (Table 17). Rice farmers in Malaysia who patronize the conventional method are in business because of the Malaysian government subsidies on fertilizers, lime, and seeds (Ibrahim and Siwar, 2012). The lower total production cost associated with conventional method (T1) is related to the use of inorganic fertilizers only and this could be one of the reasons why most farmers adopt this practice. As reported by Schepers et al. (1991), the lower total production cost which is related to the standard fertilization coupled with the convenience of not splitting the inorganic fertilizers application during the growing season is attractive to farmers. In this regard, excess inorganic fertilizers are applied as insurance, and because farmers often are overly optimistic concerning expected yields and yield goals (Schepers et al., 1991). Because of this, the affordability of fertilizers in the developed world has led to its misuse and over application but the opposite is true for the developing world, where access to inorganic fertilizers is limited, especially for subsistence farmers in remote areas (Hubbell, 1995).

Regardless of field trial, the use of crude humic substances (T2) in the rice cultivation is economically viable (Tables 6, 10, and 14). The net revenue for adopting T2 was higher in the second field trial because of the reduction in crude humic substances (compost and ash) and chemical fertilizers use. For every RM 1 spent in adopting T2, RM 1.84, RM 2.25, and RM 1.68 were gained in return in the first, second, and third field trials, respectively (Table 17). In terms of net present value, a comparison between the conventional rice cultivation (T1) and crude humic substances application (T2) shows that T2 is more economically viable regardless of planting cycle (Table 17). This suggests that rice growers can adopt T2 so as to avoid reduction in NPV especially in the third planting cycle where lower cost of production is involved. Moreover, rice farmers can increase their profits if they produce and use their own composts from their rice straw and rice husk after harvesting their crop. The added benefit associated with this proposition is that it could prevent open burning of for example, rice straw and husk, thus, contributing to reduction of environmental pollution.

Except for the first field trial, the chicken litter biochar treatment (T3) showed higher net revenue than with the conventional method (T1). The net revenues for the field trials were in the order of first field trial < second field trial < third field trial (Tables 7, 11, and 15). The economic loss in the first field trial for incorporating chicken litter biochar in the rice cultivation was due to the higher cost of this organic amendment. For every RM 1 spent for adopting T3 in lowland rice cultivation, RM 0.92, RM 1.50, and RM 3.27 were gained in return in the first, second, and third field trials, respectively (Table 17). Comparing the NPV associated with the conventional rice cultivation (T1) and the chicken litter biochar method (T3), T3 is more economically viable in second and third field trials (Table 17). In the first field trial, T3 showed RM 0.08 loss for every RM 1 spent however, this loss can be reduced if rice farmers are able to produce their own biochar from rice straw and rice husk. The economic analysis shows that by adopting the chicken litter biochar approach, rice farmers can breakeven in the second cycle of planting rice. Moreover, the highest net revenue, BCR and NPV of chicken litter biochar in the third field trial indicates that this amendment had residual effect as T3 showed the highest yield and profit compared with T1, T2, and T4. Thus, the chicken litter biochar treatment (T3) is economically viable and sustainable. Considering that farmers may not be able to afford the high cost of inorganic fertilizers, the use of organic inputs or their combination with inorganic fertilizers could form a major complement to replenish nutrients deficiencies and at the same time ensuring high crop yields.

In the third field trial, T4 was economically viable because in this trial, the production cost was lower compared with those of the first and second field trials (Tables 8, 12, and 16). For every RM 1 spent in incorporating clinoptilolite zeolite (T4) in rice cultivation, the losses were RM 0.30 and RM 0.02 in the first and second field trials, respectively. However, in the third field trial, a profit of RM 0.21 was possible for every RM 1 spent (Table 17). The net present value for adopting T4 was better that the conventional method (T1) (Table 17). Thus, clinoptilolite zeolite treatment (T4) is economically not viable in short-term. This implies that for long term, clinoptilolite zeolite treatment (T4) is a profitable investment.

Conclusion

Results revealed that long-term cultivation of rice based on conventional method is not economically sustainable. Regardless of cropping cycle, crude humic substances were economically viable. Farmers who include chicken litter biochar or clinoptilolite zeolite in their rice cultivation can breakeven in the second and third field planting cycles. Incorporating crude humic substances is the most economical practice in rice cultivation followed by chicken littler biochar or clinoptilolite zeolite.

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Table 5. Costs and revenues associated with conventional method of cultivating rice (T1) (first trial)

	Price per unit (RM)	Quantity	RM ha^{-1}
OPERATING EXPENSES			
Field preparation	81 ha^{-1} $cycle^{-1}$	1 cycle	81.00
Ploughing	315 ha^{-1} $cycle^{-1}$	1 cycle	315.00
Liming	5 bag^{-1}	56 bags ha^{-1}	280.00
Nursing and transplanting	500 ha^{-1} $cycle^{-1}$	1 cycle	500.00
Herbicide spraying	460 ha^{-1} $cycle^{-1}$	1 cycle	460.00
Insecticide spraying	225 ha^{-1} $cycle^{-1}$	1 cycle	225.00
Fertilizer application	5 bag^{-1}	20 bags ha^{-1}	100.00
Harvesting	40 t^{-1}	7.19 t ha^{-1}	287.60
Transport	30 t^{-1}	7.19 t ha^{-1}	215.70
FIELD MATERIALS			
Lime	540 t^{-1}	2.8 t ha^{-1}	1,512.00
Seeds	100 bag^{-1}	3 bags ha^{-1}	300.00
Herbicide	100 ha^{-1} $cycle^{-1}$	1 cycle	100.00
Insecticide	250 ha^{-1} $cycle^{-1}$	1 cycle	250.00
Fertilizers			
Urea	76 bag^{-1} (50 kg)	328 kg ha^{-1}	498.56
ERP	34 bag^{-1} (50 kg)	349 kg ha^{-1}	237.32
MOP	85 bag^{-1} (50 kg)	159 kg ha^{-1}	270.30
Kieserite	27 bag^{-1} (50 kg)	42 kg ha^{-1}	22.68
ZnCoBor	143 bag^{-1} (25 kg)	133 kg ha^{-1}	760.76
OTHER COST			
Land rental*			
Miscellaneous			320.80
TOTAL COST			6,736.72
REVENUE			
Yield	1200 t^{-1}	7.19 t ha^{-1}	8,628.00
Incentive	650 t^{-1} yield increase	0 t ha^{-1}	0.00
TOTAL REVENUE			8,628.00
NET REVENUE			1,891.28

*if the rice field is rented; These estimations were done on January 2016

Table 6. Costs and revenues associated with crude humic substances application (T2) (first trial)

	Price per unit (RM)	Quantity	RM ha^{-1}
OPERATING EXPENSES			
Field preparation	81 ha^{-1} $cycle^{-1}$	1 cycle	81.00
Ploughing	315 ha^{-1} $cycle^{-1}$	1 cycle	315.00
Nursing and transplanting	500 ha^{-1} $cycle^{-1}$	1 cycle	500.00
Herbicide spraying	460 ha^{-1} $cycle^{-1}$	1 cycle	460.00
Insecticide spraying	225 ha^{-1} $cycle^{-1}$	1 cycle	225.00
Fertilizer application	5 bag^{-1}	20 bags ha^{-1}	100.00
Harvesting	40 t^{-1}	10.54 t ha^{-1}	421.60
Transport	30 t^{-1}	10.54 t ha^{-1}	316.20
FIELD MATERIALS			
Seeds	100 bag^{-1}	3 bags ha^{-1}	300.00
Herbicide	100 ha^{-1} $cycle^{-1}$	1 cycle	100.00
Insecticide	250 ha^{-1} $cycle^{-1}$	1 cycle	250.00
Fertilizers			
Urea	76 bag^{-1} (50 kg)	328 kg ha^{-1}	498.56
ERP	34 bag^{-1} (50 kg)	349 kg ha^{-1}	237.32
MOP	85 bag^{-1} (50 kg)	159 kg ha^{-1}	270.30
Kieserite	27 bag^{-1} (50 kg)	42 kg ha^{-1}	22.68
ZnCoBor	143 bag^{-1} (25 kg)	133 kg ha^{-1}	760.76
Compost	500 t^{-1}	5 t ha^{-1}	2,500.00
Ash	400 t^{-1}	0.5 t ha^{-1}	200.00
OTHER COST			
Land rental*			
Miscellaneous			377.92
TOTAL COST			7,936.34
REVENUE			
Yield	1200 t^{-1}	10.54 t ha^{-1}	12,648.00
Incentive	650 t^{-1} yield increase	3 t ha^{-1}	1,950.00
TOTAL REVENUE			14,598.00
NET REVENUE			6,661.66

*if the rice field is rented; These estimations were done on January 2016

Table 7. Costs and revenues associated with chicken litter biochar application (T3) (first trial)

	Price per unit (RM)	Quantity	RM ha^{-1}
OPERATING EXPENSES			
Field preparation	81 ha^{-1} $cycle^{-1}$	1 cycle	81.00
Ploughing	315 ha^{-1} $cycle^{-1}$	1 cycle	315.00
Nursing and transplanting	500 ha^{-1} $cycle^{-1}$	1 cycle	500.00
Herbicide spraying	460 ha^{-1} $cycle^{-1}$	1 cycle	460.00
Insecticide spraying	225 ha^{-1} $cycle^{-1}$	1 cycle	225.00
Fertilizer application	5 bag^{-1}	20 bags ha^{-1}	100.00
Harvesting	40 t^{-1}	13.52 t ha^{-1}	540.80
Transport	30 t^{-1}	13.52 t ha^{-1}	405.60
FIELD MATERIALS			
Seeds	100 bag^{-1}	3 bags ha^{-1}	300.00
Herbicide	100 ha^{-1} $cycle^{-1}$	1 cycle	100.00
Insecticide	250 ha^{-1} $cycle^{-1}$	1 cycle	250.00
Fertilizers			
Urea	76 bag^{-1} (50 kg)	328 kg ha^{-1}	498.56
ERP	34 bag^{-1} (50 kg)	349 kg ha^{-1}	237.32
MOP	85 bag^{-1} (50 kg)	159 kg ha^{-1}	270.30
Kieserite	27 bag^{-1} (50 kg)	42 kg ha^{-1}	22.68
ZnCoBor	143 bag^{-1} (25 kg)	133 kg ha^{-1}	760.76
Biochar	1050 t^{-1}	15 t ha^{-1}	15,750.00
OTHER COST			
Land rental*			
Miscellaneous			1,040.85
TOTAL COST			21,857.87
REVENUE			
Yield	1200 t^{-1}	13.52 t ha^{-1}	16,224.00
Incentive	650 t^{-1} yield increase	6 t ha^{-1}	3,900.00
TOTAL REVENUE			20,124.00
NET REVENUE			-1,733.87

*if the rice field is rented; These estimations were done on January 2016

Table 8. Costs and revenues associated with clinoptilolite zeolite application (T4) (first trial)

	Price per unit (RM)	Quantity	RM ha^{-1}
OPERATING EXPENSES			
Field preparation	81 ha^{-1} $cycle^{-1}$	1 cycle	81.00
Ploughing	315 ha^{-1} $cycle^{-1}$	1 cycle	315.00
Nursing and transplanting	500 ha^{-1} $cycle^{-1}$	1 cycle	500.00
Herbicide spraying	460 ha^{-1} $cycle^{-1}$	1 cycle	460.00
Insecticide spraying	225 ha^{-1} $cycle^{-1}$	1 cycle	225.00
Fertilizer application	5 bag-1	20 bags	100.00
Harvesting	40 t^{-1}	8.29 t ha^{-1}	331.60
Transport	30 t^{-1}	8.29 t ha^{-1}	248.70
FIELD MATERIALS			
Seeds	100 bag^{-1}	3 bags ha^{-1}	300.00
Herbicide	100 ha^{-1} $cycle^{-1}$	1 cycle	100.00
Insecticide	250 ha^{-1} $cycle^{-1}$	1 cycle	250.00
Fertilizers			
Urea	76 bag^{-1} (50 kg)	328 kg ha^{-1}	498.56
ERP	34 bag^{-1} (50 kg)	349 kg ha^{-1}	237.32
MOP	85 bag^{-1} (50 kg)	159 kg ha^{-1}	270.30
Kieserite	27 bag^{-1} (50 kg)	42 kg ha^{-1}	22.68
ZnCoBor	143 bag^{-1} (25 kg)	133 kg ha^{-1}	760.76
Clinoptilolite zeolite	650 t^{-1}	15 t ha^{-1}	9,750.00
OTHER COST			
Land rental*			
Miscellaneous			722.55
TOTAL COST			15,173.47
REVENUE			
Yield	1200 t^{-1}	8.29 t ha^{-1}	9,948.00
Incentive	650 t^{-1} yield increase	1 t ha^{-1}	650.00
TOTAL REVENUE			10,598.00
NET REVENUE			-4,575.47

*if the rice field is rented; These estimations were done on January 2016

Table 9. Cost and revenue associated with conventional method (T1) (second trial)

	Price per unit (RM)	Quantity	RM ha^{-1}
OPERATING EXPENSES			
Field preparation	81 ha^{-1} $cycle^{-1}$	1 cycle	81.00
Ploughing	315 ha^{-1} $cycle^{-1}$	1 cycle	315.00
Liming	5 bag^{-1}	56 bags ha^{-1}	280.00
Nursing and transplanting	500 ha^{-1} $cycle^{-1}$	1 cycle	500.00
Herbicide spraying	460 ha^{-1} $cycle^{-1}$	1 cycle	460.00
Insecticide spraying	225 ha^{-1} $cycle^{-1}$	1 cycle	225.00
Fertilizer application	5 bag-1	20 bags	100.00
Harvesting	40 t^{-1}	6.44 t ha^{-1}	257.60
Transport	30 t^{-1}	6.44 t ha^{-1}	193.20
FIELD MATERIALS			
Lime	540 30 t^{-1}	2.8 t ha^{-1}	1,512.00
Seeds	100 bag^{-1}	3 bags ha^{-1}	300.00
Herbicide	100 ha^{-1} $cycle^{-1}$	1 cycle	100.00
Insecticide	250 ha^{-1} $cycle^{-1}$	1 cycle	250.00
Fertilizers			
Urea	76 bag^{-1} (50 kg)	328 kg ha^{-1}	498.56
ERP	34 bag^{-1} (50 kg)	349 kg ha^{-1}	237.32
MOP	85 bag^{-1} (50 kg)	159 kg ha^{-1}	270.30
Kieserite	27 bag^{-1} (50 kg)	42 kg ha^{-1}	22.68
ZnCoBor	143 bag^{-1} (25 kg)	133 kg ha^{-1}	760.76
OTHER COST			
Land rental*			
Miscellaneous			318.17
TOTAL COST			6,681.59
VENUE			
Yield	1200 t^{-1}	6.44 t ha^{-1}	7,728.00
Incentive	650 t^{-1} yield increase	0 t ha^{-1}	0.00
TOTAL REVENUE			7,728.00
NET REVENUE			1,046.41

*if the rice field is rented; These estimations were done on January 2016

Table 10. Costs and revenues associated with crude humic substances application (T2) (second trial)

	Price per unit (RM)	Quantity	RM ha^{-1}
OPERATING EXPENSES			
Field preparation	81 ha^{-1} $cycle^{-1}$	1 cycle	81.00
Ploughing	315 ha^{-1} $cycle^{-1}$	1 cycle	315.00
Nursing and transplanting	500 ha^{-1} $cycle^{-1}$	1 cycle	500.00
Herbicide spraying	460 ha^{-1} $cycle^{-1}$	1 cycle	460.00
Insecticide spraying	225 ha^{-1} $cycle^{-1}$	1 cycle	225.00
Fertilizer application	5 bag^{-1}	13 bags ha^{-1}	65.00
Harvesting	40 t^{-1}	10.11 t ha^{-1}	404.40
Transport	30 t^{-1}	10.11 t ha^{-1}	303.30
FIELD MATERIALS			
Seeds	100 bag^{-1}	3 bags ha^{-1}	300.00
Herbicide	100 ha^{-1} $cycle^{-1}$	1 cycle	100.00
Insecticide	250 ha^{-1} $cycle^{-1}$	1 cycle	250.00
Fertilizers			
Urea	76 bag^{-1} (50 kg)	191 kg ha^{-1}	290.32
ERP	34 bag^{-1} (50 kg)	150 kg ha^{-1}	102.00
MOP	85 bag^{-1} (50 kg)	99 kg ha^{-1}	168.30
Kieserite	27 bag^{-1} (50 kg)	42 kg ha^{-1}	22.68
ZnCoBor	143 bag^{-1} (25 kg)	133 kg ha^{-1}	760.76
Compost	500 t^{-1}	1.67 t ha^{-1}	835.00
Ash	400 t^{-1}	167 kg ha^{-1}	66.80
OTHER COST			
Land rental*			
Miscellaneous			262.48
TOTAL COST			5,512.04
REVENUE			
Yield	1200 t^{-1}	10.11 t ha^{-1}	12,132.00
Incentive	650 t^{-1} yield increase	3 t ha^{-1}	1,950.00
TOTAL REVENUE			14,082.00
NET REVENUE 8,569.96			

*if the rice field is rented; These estimations were done on January 2016

Table 11. Costs and revenues associated with chicken litter biochar application (T3) (second trial)

	Price per unit (RM)	Quantity	RM ha^{-1}
OPERATING EXPENSES			
Field preparation	81 ha^{-1} $cycle^{-1}$	1 cycle	81.00
Ploughing	315 ha^{-1} $cycle^{-1}$	1 cycle	315.00
Nursing and transplanting	500 ha^{-1} $cycle^{-1}$	1 cycle	500.00
Herbicide spraying	460 ha^{-1} $cycle^{-1}$	1 cycle	460.00
Insecticide spraying	225 ha^{-1} $cycle^{-1}$	1 cycle	225.00
Fertilizer application	5 bag^{-1}	13 bags ha^{-1}	65.00
Harvesting	40 t^{-1}	10.47 t ha^{-1}	418.80
Transport	30 t^{-1}	10.47 t ha^{-1}	314.10
FIELD MATERIALS			
Seeds	100 bag^{-1}	3 bags ha^{-1}	300.00
Herbicide	100 ha^{-1} $cycle^{-1}$	1 cycle	100.00
Insecticide	250 ha^{-1} $cycle^{-1}$	1 cycle	250.00
Fertilizers			
Urea	76 bag^{-1} (50 kg)	191 kg ha^{-1}	290.32
ERP	34 bag^{-1} (50 kg)	150 kg ha^{-1}	102.00
MOP	85 bag^{-1} (50 kg)	99 kg ha^{-1}	168.30
Kieserite	27 bag^{-1} (50 kg)	42 kg ha^{-1}	22.68
ZnCoBor	143 bag^{-1} (25 kg)	133 kg ha^{-1}	760.76
Biochar	1050 t^{-1}	5 t ha^{-1}	5,250.00
OTHER COST			
Land rental*			
Miscellaneous			481.15
TOTAL COST			10,104.11
REVENUE			
Yield	1200 t^{-1}	10.47 t ha^{-1}	12,564.00
Incentive	650 t^{-1} yield increase	4 t ha^{-1}	2,600.00
TOTAL REVENUE			15,164.00
NET REVENUE			5,059.89

*if the rice field is rented; These estimations were done on January 2016

Table 12. Costs and revenues associated with clinoptilolite zeolite application (T4) (second trial)

	Price per unit (RM)	Quantity	RM ha^{-1}
OPERATING EXPENSES			
Field preparation	81 ha^{-1} $cycle^{-1}$	1 cycle	81.00
Ploughing	315 ha^{-1} $cycle^{-1}$	1 cycle	315.00
Nursing and transplanting	500 ha^{-1} $cycle^{-1}$	1 cycle	500.00
Herbicide spraying	460 ha^{-1} $cycle^{-1}$	1 cycle	460.00
Insecticide spraying	225 ha^{-1} $cycle^{-1}$	1 cycle	225.00
Fertilizer application	5 bag-1	8 bags	40.00
Harvesting	40 t^{-1}	5.97 t ha^{-1}	238.80
Transport	30 t^{-1}	5.97 t ha^{-1}	179.10
FIELD MATERIALS			
Seeds	100 bag^{-1}	3 bags ha^{-1}	300.00
Herbicide	100 ha^{-1} $cycle^{-1}$	1 cycle	100.00
Insecticide	250 ha^{-1} $cycle^{-1}$	1 cycle	250.00
Fertilizers			
Urea	76 bag^{-1} (50 kg)	91 kg ha^{-1}	498.56
ERP	34 bag^{-1} (50 kg)	150 kg ha^{-1}	237.32
MOP	85 bag^{-1} (50 kg)	99 kg ha^{-1}	270.30
Kieserite	27 bag^{-1} (50 kg)	27 kg ha^{-1}	22.68
ZnCoBor	143 bag^{-1} (25 kg)	0 kg ha^{-1}	0.00
Clinoptilolite zeolite	650 t^{-1}	5 t ha^{-1}	3,250.00
OTHER COST			
Land rental*			
Miscellaneous			348.39
TOTAL COST			7,316.15
REVENUE			
Yield	1200 t^{-1}	5.97 t ha^{-1}	7,164.00
Incentive	650 t^{-1} yield increase	0 t ha^{-1}	0.00
TOTAL REVENUE			7,164.00
NET REVENUE			-152.15

*if the rice field is rented; These estimations were done on January 2016

Table 13. Costs and revenues associated with conventional method (T1) (third trial)

	Price per unit (RM)	Quantity	RM ha^{-1}
OPERATING EXPENSES			
Field preparation	81 ha^{-1} $cycle^{-1}$	1 cycle	81.00
Ploughing	315 ha^{-1} $cycle^{-1}$	1 cycle	315.00
Liming	5 bag^{-1}	56 bags ha^{-1}	280.00
Nursing and transplanting	500 ha^{-1} $cycle^{-1}$	1 cycle	500.00
Herbicide spraying	460 ha^{-1} $cycle^{-1}$	1 cycle	460.00
Insecticide spraying	225 ha^{-1} $cycle^{-1}$	1 cycle	225.00
Fertilizer application	5 bag-1	18 bags	90.00
Harvesting	40 t^{-1}	3.42 t ha^{-1}	136.80
Transport	30 t^{-1}	3.42 t ha^{-1}	102.60
FIELD MATERIALS			
Lime	540 30 t^{-1}	2.8 t ha^{-1}	1,512.00
Seeds	100 bag^{-1}	3 bags ha^{-1}	300.00
Herbicide	100 ha^{-1} $cycle^{-1}$	1 cycle	100.00
Insecticide	250 ha^{-1} $cycle^{-1}$	1 cycle	250.00
Fertilizers			
Urea	76 bag^{-1} (50 kg)	328 kg ha^{-1}	498.56
ERP	34 bag^{-1} (50 kg)	349 kg ha^{-1}	237.32
MOP	85 bag^{-1} (50 kg)	159 kg ha^{-1}	270.30
Kieserite	27 bag^{-1} (50 kg)	27 kg ha^{-1}	14.58
ZnCoBor	143 bag^{-1} (25 kg)	0 kg ha^{-1}	0.00
OTHER COST			
Land rental*			
Miscellaneous			268.66
TOTAL COST			5,641.82
REVENUE			
Yield	1200 t^{-1}	3.42 t ha^{-1}	4,104.00
Incentive	650 t^{-1} yield increase	0 t ha^{-1}	0.00
TOTAL REVENUE			4,104.00
NET REVENUE			-1,537.82

*if the rice field is rented; These estimations were done on January 2016

Table 14. Costs and revenues associated with crude humic substances application (T2) (third trial)

	Price per unit (RM)	Quantity	RM ha^{-1}
OPERATING EXPENSES			
Field preparation	81 ha^{-1} $cycle^{-1}$	1 cycle	81.00
Ploughing	315 ha^{-1} $cycle^{-1}$	1 cycle	315.00
Nursing and transplanting	500 ha^{-1} $cycle^{-1}$	1 cycle	500.00
Herbicide spraying	460 ha^{-1} $cycle^{-1}$	1 cycle	460.00
Insecticide spraying	225 ha^{-1} $cycle^{-1}$	1 cycle	225.00
Fertilizer application	5 bag-1	4 bags	20.00
Harvesting	40 t^{-1}	4.17 t ha^{-1}	166.80
Transport	30 t^{-1}	4.17 t ha^{-1}	125.10
FIELD MATERIALS			
Seeds	100 bag^{-1}	3 bags ha^{-1}	300.00
Herbicide	100 ha^{-1} $cycle^{-1}$	1 cycle	100.00
Insecticide	250 ha^{-1} $cycle^{-1}$	1 cycle	250.00
Fertilizers			
Urea	76 bag^{-1} (50 kg)	191 kg ha^{-1}	290.32
ERP	34 bag^{-1} (50 kg)	0 kg ha^{-1}	0.00
MOP	85 bag^{-1} (50 kg)	0 kg ha^{-1}	0.00
Kieserite	27 bag^{-1} (50 kg)	0 kg ha^{-1}	0.00
ZnCoBor	143 bag^{-1} (25 kg)	0 kg ha^{-1}	0.00
Compost	500 t^{-1}	0 t ha^{-1}	0.00
Ash	400 t^{-1}	0 t ha^{-1}	0.00
OTHER COST			
Land rental*			
Miscellaneous			141.66
TOTAL COST			2,974.88
REVENUE			
Yield	1200 t^{-1}	4.17 t ha^{-1}	5,004.00
Incentive	650 t^{-1} yield increase	0 t ha^{-1}	0.00
TOTAL REVENUE			5,004.00
NET REVENUE			2,029.12

*if the rice field is rented; These estimations were done on January 2016.

Table 15. Costs and revenues associated with chicken litter biochar application (T3) (third trial)

	Price per unit (RM)	Quantity	RM ha^{-1}
OPERATING EXPENSES			
Field preparation	81 ha^{-1} $cycle^{-1}$	1 cycle	81.00
Ploughing	315 ha^{-1} $cycle^{-1}$	1 cycle	315.00
Nursing and transplanting	500 ha^{-1} $cycle^{-1}$	1 cycle	500.00
Herbicide spraying	460 ha^{-1} $cycle^{-1}$	1 cycle	460.00
Insecticide spraying	225 ha^{-1} $cycle^{-1}$	1 cycle	225.00
Fertilizer application	5 bag-1	4 bags	20.00
Harvesting	40 t^{-1}	7.05 t ha^{-1}	282.00
Transport	30 t^{-1}	7.05 t ha^{-1}	211.50
FIELD MATERIALS			
Seeds	100 bag^{-1}	3 bags ha^{-1}	300.00
Herbicide	100 ha^{-1} $cycle^{-1}$	1 cycle	100.00
Insecticide	250 ha^{-1} s $cycle^{-1}$	1 cycle	250.00
Fertilizers			
Urea	76 bag^{-1} (50 kg)	191 kg ha^{-1}	290.32
ERP	34 bag^{-1} (50 kg)	0 kg ha^{-1}	0.00
MOP	85 bag^{-1} (50 kg)	0 kg ha^{-1}	0.00
Kieserite	27 bag^{-1} (50 kg)	0 kg ha^{-1}	0.00
ZnCoBor	143 bag^{-1} (25 kg)	0 kg ha^{-1}	0.00
Biochar	1050 t^{-1}	0 t ha^{-1}	0.00
OTHER COST			
Land rental*			
Miscellaneous			151.74
TOTAL COST			3,186.56
REVENUE			
Yield	1200 t^{-1}	7.05 t ha^{-1}	8,460.00
Incentive	650 t^{-1} yield increase	3 t ha^{-1}	1,950.00
TOTAL REVENUE			10,410.00
NET REVENUE			7223.44

*if the rice field is rented; These estimations were done on January 2016.

Table 16. Costs and revenues associated with clinoptilolite zeolite application (T4) (third trial)

	Price per unit (RM)	Quantity	RM ha^{-1}
OPERATING EXPENSES			
Field preparation	81 ha^{-1} $cycle^{-1}$	1 cycle	81.00
Ploughing	315 ha^{-1} $cycle^{-1}$	1 cycle	315.00
Nursing and transplanting	500 ha^{-1} $cycle^{-1}$	1 cycle	500.00
Herbicide spraying	460 ha^{-1} $cycle^{-1}$	1 cycle	460.00
Insecticide spraying	225 ha^{-1} $cycle^{-1}$	1 cycle	225.00
Fertilizer application	5 bag^{-1}	1 bag	50.00
Harvesting	40 t^{-1}	2.70 t ha^{-1}	108.00
Transport	30 t^{-1}	2.70 t ha^{-1}	81.00
FIELD MATERIALS			
Seeds	100 bag^{-1}	3 bags ha^{-1}	300.00
Herbicide	100 ha^{-1} $cycle^{-1}$	1 cycle	100.00
Insecticide	250 ha^{-1} s $cycle^{-1}$	1 cycle	250.00
Fertilizers			
Urea	76 bag^{-1} (50 kg)	46 kg ha^{-1}	69.92
ERP	34 bag^{-1} (50 kg)	0 kg ha^{-1}	0.00
MOP	85 bag^{-1} (50 kg)	0 kg ha^{-1}	0.00
Kieserite	27 bag^{-1} (50 kg)	0 kg ha^{-1}	0.00
ZnCoBor	143 bag^{-1} (25 kg)	0 kg ha^{-1}	0.00
Clinoptilolite zeolite	650 t^{-1}	0 t ha^{-1}	0.00
OTHER COST			
Land rental*			
Miscellaneous			127.00
TOTAL COST			2666.92
REVENUE			
Yield	1200 t^{-1}	2.70 t ha^{-1}	3,240.00
Incentive	650 t^{-1} yield increase	0 t ha^{-1}	0.00
TOTAL REVENUE			3,240.00
NET REVENUE			573.08

*if the rice field is rented; These estimations were done on January 2016.

Table 17. Effects of different practices on benefit-cost ratio (BCR) and net present value (NPV)

Treat-ment	First plant cycle		Second plant cycle		Third plant cycle	
	BCR	NPV (RM ha^{-1})	BCR	NPV (RM ha^{-1})	BCR	NPV (RM ha^{-1})
T1	1.28	1836.19	1.16	1015.93	0.73	-1493.03
T2	1.84	6467.63	2.55	8320.35	1.68	1970.02
T3	0.92	-1683.37	1.50	4912.51	3.27	7013.05
T4	0.70	-4442.20	0.98	-147.72	1.21	556.39

T1 – conventional practice; T2 – crude humic substances; T3 – chicken litter biochar; T4 – clinoptilolite zeolite