Effect of Adding Appropriate Mixture of NPK and Chicken Manure on Growth and Yield of TR-9 Paddy Variety on Beach Ridges Interspersed with Swales (BRIS) Soil

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Summary

Conversion of fertile lands to other uses has been one of limiting factors for paddy production in Malaysia. Infertile soil such as Beach Ridges Interspersed with Swales (BRIS) soil has a potential for paddy production if it's fertility has been improved. We, therefore, conducted a study to determine the optimum rate of NPK and chicken manure for growth and yield of TR-9 paddy variety grown on BRIS soil and also to determine the nutrient content of the BRIS soil after different high application rates of NPK and chicken manure. Treatments were three NPK rates at 60:30:30 kg ha^{-1}, 100:60:60 kg ha^{-1} and 150:90:90 kg ha^{-1}, and three chicken manure rates at 20 t ha^{-1}, 40 t ha^{-1} and 60 t ha^{-1}, arranged in a complete randomized design. Our results showed that TR-9 paddy variety growth and yield were not significantly affected by combination of NPK and chicken manure when grown on BRIS soil. NPK rate of 60:30:30 kg ha^{-1} produced the highest percentage of productive tillers (71.62 %) and 1000 grains weight (24.73 g). Chicken manure rate of 20 t ha^{-1} produced the highest plant height (127.75 cm), culm height (85.58 cm), percentage of filled grains (83.73 %), 1000 grains weight (25.81 g), extrapolated yield (11.16 tons ha^{-1}) and dry weight (464.44 g). Furthermore, application of high NPK and chicken manure to BRIS soil have significantly increased soil nutrients and organic carbon content which in turn can promote better growth and yield.

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Key words : TR-9 paddy variety, BRIS soil, NPK, Chicken manure

INTRODUCTION

Rice is cultivated in over 100 countries around the world. It provides more than 22 % of global energy intake (Kainuma, 2004). In Malaysia, rice is the main staple food and is a strategically important commodity for her food security. Malaysia used 671,679 hectares of area for planting paddy and had 2,604,00 metric tonnes of paddy production in 2013 (Ministry of Agriculture and Agro-Based Industry, 2014).

Traditionally, almost all the paddy lands in Malaysia were cultivated with rice. Over the years, however, these particular lands have been diverted for other agricultural as well as non-agricultural uses or simply abandoned. Consequently, land suitable for paddy cultivation has become limited, restricting continuation of paddy farming and leading to food security issues. Thus, much of the agriculture in developing countries is practised on marginally suitable soil, such as Beach Ridges Interspersed with Swales (BRIS) soil, to plant food crops such as paddy in order to overcome food security issues.

There are about 2 million people depending on this poor BRIS soil for economic survival in Malaysia (Melisa *et al.*, 2011). Therefore, the need for their improvement is important to address. BRIS soil is a problem soil which contains more than 90 % sand, is low in water holding capacity, low in nutrients and organic water content (Zaki and Mustafa, 2005). Although BRIS soil has limitations for crop production due to its inferior physical and chemical properties, it has potential to produce rice if its fertility is improved. To improve BRIS soil fertility, chemical and organic fertilizers could be incorporated as they are effective in restoring the productivity of degraded soils with poor characteristics.

MATERIALS AND METHODS

This study was conducted in the net house of Faculty of Sustainable Agriculture (FSA), Universiti Malaysia Sabah (UMS), Sandakan, Malaysia, from 15 April 2014 to 15 October 2014. Treatments were arranged in complete randomized design with three replications. Factor one was three different NPK rates, which is 60:30:30, 100:60:60, and 150:90:90 kg ha^{-1}, while factor two was three different chicken manure rates, which is 20, 40, and 60 t ha^{-1}.

Twenty-seven clay pots with the diameter 30 cm were transplanted with two paddy seedlings in each pot and each seedling was at 20 cm planting distance away from the other. Each paddy seedling was tied loosely to a bamboo stick for upright support to the seedlings, to fix their positions and avoid toppling. The treatments in this study were the incorporation of the NPK fertilizer with chicken manure

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under different application rates. Split application of mineral fertilizer of urea (N), Triple Super Phosphate (TSP), and Muriate of Potash (MOP) was done in three times, which is as basal application three days before transplanting, as topdressing during active tillering, and as topdressing during panicle initiation, whereas split application of chicken manure was done two times, which is as basal application at least 2 weeks (due to longer time for complete decomposition) before transplanting and as topdressing during maximum tillering.

Parameters measured for paddy vegetative growth were plant height (cm), number of tillers, culm height (cm), and percentage of productive tillers. Parameters for paddy yield was panicle number; length of panicles (cm), percentage of filled grains (%), percentage of empty grains (%), weight of 1000 grains (g), extrapolated yield (tons ha^{-1}), and dry weight (g). Parameters for soil analysis included soil total nitrogen content, soil available phosphorus, exchangeable potassium, soil pH, soil organic matter, and cation exchange capacity.

Data collected was statistically analyzed by using two-way analysis of variance (ANOVA) and the significant differences were analysed using Tukey's test at $P<0.05$.

RESULTS

Paddy vegetative growth and yield components

The results revealed no significant effects of NPK and interaction effects of NPK fertilizer and chicken manure on the plant height, number of tillers, culm height, percentage of productive tillers, number of panicles, length of panicle, percentage of filled grains, percentage of empty grains, weight of 1000 grains, extrapolated yield and dry weight of the paddy (Table 1 and 2). However, the effect of the chicken manure was significant on parameters for vegetative growth and yield component of the paddy.

NPK rate of 60:30:30 kg ha^{-1} produced the highest percentage of productive tillers (71.62 %) and 1000 grains

Table 1. Effect of different NPK and chicken manure rates on paddy vegetative growth

Treatment	Plant Height (cm)	Culm Height (cm)	Tiller Numbers	Percentage of Productive Tillers (%)
NPK Rate (kg ha^{-1})				
60:30:30	113.08^a	79.21^a	36.33^a	71.62^a
100:60:60	120.44^a	82.37^a	42.00^a	69.10^a
150:90:90	118.14^a	78.59a	41.44^a	64.61^a
Chicken Manure Rate (t ha^{-1})				
20	127.75^a	85.58^a	43.11^{ab}	67.52^a
40	108.39^b	80.25^a	45.22^a	79.37^b
60	115.53^b	74.34^b	31.44^b	58.45^a

* Values with different letters within columns are significantly different at $P≤0.05$.

Table 2. Effect of different NPK and chicken manure rates on paddy yield components.

Treatment	Panicle Number	Panicle Length (cm)	Percentage of Filled Grains (%)	Percentage of Empty Grains (%)	1,000 Grains Weight (g)	Extrapolated Yield (tons ha^{-1})	Dry Weight (g)
NPK Rate (kg ha^{-1})							
60:30:30	30.22^a	23.94^a	70.64^a	29.36^a	24.73^a	8.11^a	337.57^a
100:60:60	32.33^a	24.13^a	74.60^a	25.40^a	24.69^a	9.16^a	418.63^a
150:90:90	31.11^a	24.57^a	67.56^a	32.44^a	23.40^a	7.79^a	390.62^a
Chicken Manure Rate (t ha^{-1})							
20	34.89^a	23.58^a	83.73^a	16.27^a	25.81^a	11.26^a	464.44^a
40	39.44^a	23.12^a	69.31^b	30.69^b	24.83^a	9.42^a	377.96^{ab}
60	19.33^b	25.95^b	59.77^c	40.23^b	22.18^b	4.38^b	304.41^b

*Values with different letters within columns are significantly different at $P≤0.05$.

Table 3. Effect of different NPK and chicken manure rates on soil chemical properties.

Treatment	Soil pH	Soil Organic Matter (%)	Cation Exchange Capacity ($cmol_{(+)}$/kg soil)	Total Nitrogen Content (%)	Available Phosphorus (ppm)	Exchangeable Potassium (ppm)
NPK Rate (kg ha^{-1})						
60:30:30	5.22^{a}	3.13^{a}	18.04^{a}	0.16^{a}	12.99^{a}	40.17^{a}
100:60:60	5.27^{a}	3.29^{a}	17.78^{a}	0.20^{a}	16.30^{b}	41.68^{a}
150:90:90	5.36^{a}	3.38^{a}	17.37^{a}	0.22^{a}	17.57^{b}	38.69^{a}
Chicken Manure Rate (t ha^{-1})						
20	5.91^{a}	2.95^{a}	16.19^{a}	0.13^{a}	7.41^{a}	16.74^{a}
40	4.86^{b}	3.27^{a}	18.00^{b}	0.20^{b}	16.92^{b}	44.78^{b}
60	5.08^{b}	3.57^{a}	19.00^{c}	0.25^{b}	22.53^{c}	59.01^{b}

* Values with different letters within columns are significantly different at $P \leq 0.05$.

weight (24.73 g). NPK rate of 100:60:60 kg ha^{-1} produced the highest plant height of 120.44 cm, tiller numbers (42), culm height (82.37 cm), panicle numbers (32), percentage of filled grains (74.60 %), extrapolated yield (9.16 tons ha^{-1}), and dry weight (418.63 g). NPK rate of 150:90:90 kg ha^{-1} only produced the highest panicle length (24.57 cm). Chicken manure rate of 20 t ha^{-1} produced the highest plant height (127.75 cm), culm height (85.58 cm), percentage of filled grains (83.73 %), 1000 grains weight (25.81 g), extrapolated yield (11.16 tons ha^{-1}) and dry weight (464.44 g). Chicken manure rate of 40 t ha^{-1} produced the highest tiller numbers (45), percentage of productive tillers (79.37 %) and panicle numbers (39). Chicken manure of 60 t ha^{-1} only produced the highest panicle length (25.95 cm).

BRIS soil chemical properties

There was no interaction effect on any parameters of the soil's chemical properties (Table 3). The soil pH, total nitrogen content, and exchangeable potassium were not significantly influenced by the different application rates of NPK fertilizer, but were significantly influenced by the different application rates of chicken manure. The soil organic matter was not significantly affected by either NPK rates or chicken manure rates, but the soil available phosphorus and cation exchange capacity were significantly affected by both NPK rates and chicken manure rates.

After the application of high NPK and chicken manure to the BRIS soil, value of pH decreased from 7.20 to 4.86-5.91, soil organic matter increased from 1.83 % to 2.95-3.57 %, cation exchange capacity increased from 3.50 $cmol_{(+)}$/kg soil to 16.19-19.00 $cmol_{(+)}$/kg soil, total nitrogen content changed from 0.06 % to 0.13-0.25 %, available phosphorus increased from 0.097 ppm to 7.41-22.53 ppm, and exchangeable potassium changed from 44.40 ppm to 16.74-59.01 ppm.

DISCUSSION

Effect of NPK and chicken manure on paddy vegetative growth and yield components

Application of nitrogen fertilizer will cause rapid increase in vegetative growth, such as, increases in height (Panda, 2010). In this study, plant height was significantly influenced by the chicken manure rates. This might be primarily due to the excessive nitrogen fertilizer rate, which, especially when applied to flooded soil can cause soil toxicity, which in turn causes oxygen in the soil to be depleted due to rapid decomposition of organic matter. Consequently, the depletion of oxygen in the soil interferes with the root activity of the paddy plant, thus affecting the nutrient uptake required for plant growth. According to Mirza *et al.* (2010), more numbers of tillers per square meter might be due to increased availability of nitrogen, which plays a vital role in cell division. Organic sources offer more balanced nutrition to the plants, especially micro nutrients which positively affect the number of tillers in plants (Miller, 2007). High application rate or organic fertilizer, when applied to the soil, will generate more heat during decomposition and can then cause soil temperatures to increase. Large amounts of organic matter take a longer time to be fully decomposed by microorganisms and prolonged heat can indirectly cause death of tillers. The culm height is related to the intermodal lengths of the number four and five culms. Lodging is mainly influenced by the lower internodal lengths of the number four or five culms. The thickness and diameter of the culms can also have an influence on lodging. According to Chang (1964), excess nitrogen fertilizer application rates will make the culms thin. Therefore, the tendency of lodging can increase. The number of panicles is associated with tiller production which is the most important yield attributing character

(Kaushal *et al*., 2010). In general, final yield is low if the percentage of productive tillers is low. The magnitude of decrease in mean percentage of productive tillers might be primarily due to successive reductions in the number of filled spikelets per panicle thereby indirectly contributing to reduction in number of panicle bearing tillers.

Bahmanyar and Mashaee (2010) stated that increasing panicle numbers per unit area is the main factor for yield increment as a result of nitrogen application. Low number of panicles produced due to low availability of nitrogen in the soil results from decomposition. Microorganisms decomposing organic matter from chicken manure must initially take up the available soil nitrogen for crop growth during the initial stage of decomposition. Decreased supply of available soil nitrogen does not enable good panicle development, resulting in a low number of panicles produced. Longer panicle length is due to nitrogen because nitrogen takes part in panicle formation as well as panicle elongation. Therefore, panicle length increased with the increase in N-fertilization. However, according to Shen *et al*. (2003), high nitrogen fertilizer application rate will stimulate vegetative growth and increase tiller numbers but will cause decrease in panicle length. Filled grain percentage in rice is reported to increase with fertilizer application (Mannan *et al*., 2010). However, the mean percentage of filled grains gradually decreased with increased chicken manure application. This might be due to higher nitrogen which causes an increase in competition for metabolic supply among tillers. In addition, spikelet sterility percentage decreases with increased nitrogen and phosphorus fertilizers (Yosef, 2013). When excessive fertilizers are applied, it can cause paddy leaves to turn green and become succulent, making them more attractive to pests. As a result, the damage by pests interferes with the development of the grain preventing filling of the grain. Therefore, the grains failed to form leading to high percentage of empty grains. The highest number of tillers may not necessarily result in the highest yield. This was supported by Ohnishi et al. (1999), who stated that the net photosynthesis of canopy, total dry matter production and grain yield could decrease with the increase in leaf development and tiller numbers. Due to the susceptibility of grains to pest attack, the weight of the grains may be influenced and decreased. Extrapolated yield is an important parameter to determine the yield of paddy plants per season. Reinke *et al*. (1994) noted that where the grain yield response is negative, yield reduction is primarily caused by a reduction in the proportion of the number of filled grains per panicle. Singh *et al*. (1995) also reported a decrease in grain yield of rice with application of high doses of N fertilizer. According to Jhan (2004), excessive nitrogen fertilizer applications lead to pest problems by increasing the birth rate, longevity and overall fitness of certain pests. As a result, severe pest attacks will cause low amounts of dry matter being accumulated, thus, the low dry weight obtained.

Effect of NPK and chicken manure on BRIS soil chemical properties

The results revealed that all the parameters of the BRIS soil chemical properties were improved after the application of high rates of NPK and chicken manure. The soil pH of the BRIS soil decreased from 7.20 to 4.86-5.91, soil organic matter increased from 1.83 % to 2.95-3.57 %, cation exchange capacity increased from 3.50 $cmol_{(+)}$/kg soil to 16.19-19.00 $cmol_{(+)}$/kg soil, total nitrogen content changed from 0.06 % to 0.13-0.25 %, available phosphorus increased from 0.097 ppm to 7.41-22.53 ppm, and exchangeable potassium changed from 44.40 ppm to 16.74-59.01 ppm. Organic acids and carbonic acid are produced during the decomposition of the organic fraction of the manure (Chang *et al*., 1991). Therefore, application of organic fertilizers may lower the soil pH. Long term applications of solid manure can result in very large increases in soil organic matter (Sommerfeldt *et al*., 1988; Hao *et al*., 2003). If manure or fertilizer N is applied at rates that exceed crop N requirements, excess NO_3 may be left in the soil after harvest and leaching risk is higher when it rains. Conversely, applying insufficient N to meet crop needs can increase NO_3 leaching by limiting crop growth and reducing uptake of water and nutrients (Campbell *et al*., 1993). Therefore, higher application rate of fertilizers on the soil tends to result in higher soil nitrogen content. Most of the phosphorus taken up by paddy plants is removed in the grain. In most soils, phosphorus is in stable organic forms and is held very strongly by precipitation and adsorption reactions. The potassium in manure is in an inorganic, highly soluble form and is considered to be 90-100 % available to crops just as with the synthetic fertilizer potassium (Schoenau and Davis, 2006). Thus, when potassium is applied to soil, it is quickly absorbed onto the soil’ s cation exchange sites, increasing exchangeable potassium concentrations in the soil. Potassium has strong influence on the strength of paddy plants associated with lodging. According to Bhiah (2010), application of potassium increased the basal stem strength of standard variety and semi-dwarf varieties. Mahbub *et al*. (2006) stated that lower nitrogen and higher potassium contents in internodes help to decrease the lodging tendency in paddy. Apart from the stem, Panda (2010) also stated that potassium will strengthen the cell walls of the paddy plant. As a result, paddy plants are more resistant to lodging. Increase in cation exchange capacity leads to enhancement of nutrients retention capacity (Brodowski *et al*., 2005). Thus, increase in soil cation exchange capacity can generally increase the ability of BRIS soils to hold nutrients which in turn can provide essential nutrients for plant uptake.

CONCLUSION

Our study showed chicken manure combined with NPK fertilizer improves soil fertility and rice crop yield. It is recommended that 100:60:60 kg ha^{-1} NPK incorporated with 20 t ha^{-1} chicken manure is a good combination for improved rice yields. This is good as it reduces the sole use of chemical fertilizers which are not only expensive but can be a hazard to soils in the long run. Chicken manure is inexpensive and readily available locally which can be easily used by local smallholder rice farmers for sustaining their crop on this type of marginal lands which is usually abandoned.

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BRIS 土壌において TR-9稲品種の成長と収量に及ぼす適切な組み合わせの NPK 肥料と鶏糞肥料の施肥効果

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要　約

マレーシアでは肥沃な土地が非農業的な用途に使用され、水稲生産の制限要因の一つとなっている。しかし、湿地に散在する浜堤（BRIS）土壌の様な痩せ地でも施肥で改良すれば水稲生産に使用可能である。そこで、我々は BRIS 土壌においてイネ品種 TR-9の成長及び収量に最適な化成肥料組成及び鶏糞の施肥量を決定し、種々の組成の化成肥料または異なる量の鶏糞を施肥した後の BRIS 土壌の栄養素含有量の違いを調査する事を目的として研究を行った。３種の化成肥料組成、60:30:30 kg ha^{-1}、100:60:60 kg ha^{-1}、150:90:90 kg ha^{-1}または３種の鶏糞量、20 t ha^{-1}、40 t ha^{-1}、60 t ha^{-1} を施肥し、完全無作為化法を用いて実験を行った。その結果、BRIS 土壌で成長させたイネ品種 TR-9の成長及び収量に対して化成肥料の組成や鶏糞施肥量の違いがもたらす影響には統計学的に有意な違いはなかった。60:30:30 kg ha^{-1} の化成肥料の施肥区では、円錐花序の付いた稈の産生能（71.62 %）と 1000 粒重（24.73 g）において、最も高い値が示された。また、20 t ha^{-1} の鶏糞施肥区では草高（127.75 cm）、稈の高さ（85.58 cm）、籾の充満率（83.73 %）、1000 粒重（25.81 g）、補外収量（11.16 tons ha^{-1}）、乾燥重量（464.44 g）において、最も高い値が示された。さらに、化成肥料または鶏糞を施肥した BRIS 土壌では、有意に土壌養分と有機炭素含有量が増加しており、イネの成長と収量の改善を促進できる事が示された。

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キーワード：TR-9稲品種、BRIS 土壌、化成肥料、鶏糞

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