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Composting increases BRIS soil health and sustains rice production

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ABSTRACT: Beach ridges interspersed with swales (BRIS) soil (> 90% of sand) is unsuitable to produce rice due to its poor physical and chemical properties. In this study, we investigated the effects of compost on BRIS soil health in relation to rice production. We measured rice yield, yield parameters, chlorophyll content, relative water content (RWC), and soil pH. The tiller and panicle numbers, filled grains per panicle, rice yield, and straw yields were significantly lower in BRIS soil than in a mixture of compost and BRIS soil. On the other hand, plant heights, 1000 seeds weight, and unfilled grains per panicle were not significantly different. Adding compost to BRIS soil significantly increased chlorophyll content but not the RWC of leaves. The pH of BRIS soil was significantly increased by the application of compost which indicates an increase of BRIS soil health. These results suggest that addition of compost to BRIS soil might improve BRIS soil health and increase rice yield.

KEYWORDS: chlorophyll content, soil pH, relative water content

INTRODUCTION

In 2025, world's farmers will be producing roughly 3 billion tons of cereals to feed an estimated human population of around 8 billion, which will require 25% more rice to meet the growing need[1,2]. Rice is the most important staple food in Asia, providing more than 40% of total calorie intake[3]. Approximately 640 million tons of rice are produced in Asia per year, which covers 90% of the world's rice production[4]. In Malaysia, rice is imported from neighbouring countries, especially from Vietnam and Thailand, with the amount valued at about RM (Malaysian ringgit) 501 million per year to fulfil the country's demand[5]. Therefore rice yield as well as land coverage for rice production in Malaysia is under pressure.

BRIS soil is commonly known as problematic soil in Malaysia. BRIS soils can be found in between 0.2–8.0 km from the sea beach which covers about 155 400 hectares in peninsular Malaysia and about 40 000 hectares in the state of Sabah[6]. BRIS soil is unsuitable to produce rice as it retains a high sandy texture (> 90%), low fertility, low cation exchange capacity, and low water holding capacity. However, there is a potential to produce rice under low water input. Previous studies concluded that a standing depth of water throughout the season is not needed for high rice yields[7,8] and alternate irrigation does not have a negative impact on rice growth and development[9].

Incorporation of compost into the soil increases organic matter[10] and microbial populations[11], improving the quality and increasing the fertility[12]. Soil structure refers to how inorganic particles (sand, silt, clay) combine with decayed organic particles (compost, humus). The application of compost improves soil aggregation[13], increases water-holding capacity[14–16], decreases bulk density, and increases pore volume[14]. Soil amended with compost appears as made up of many round and irregular aggregates giving it a crumbly appearance[17,18]. The compost helps the soil to recover from extreme conditions. Sandy soils have a rapid drainage and compost can help by adding more volume with humus and organic matter[16]. The addition of compost to BRIS soil to improve BRIS soil health is a new issue to increase rice production in Malaysia. Accordingly, this study was conducted to justify the effects of compost on BRIS soil health in relation to rice production. Our study confirmed that rice can be cultivated on BRIS soil but short- and long-term strategies should be taken to improve BRIS soil health and develop resistant rice cultivars.

MATERIALS AND METHODS

Agronomic practices

Pot experiments were carried out at the KUSZA campus, Universiti Sultan Zainal Abidin, Malaysia. Rice plants were grown in a pot measuring 25 cm × 25 cm × 35 cm. The soil was filled up to 30 cm height leaving a 5 cm space from the top of the pot for agronomic practices. Treatments were laid out in a completely randomized design consisting of five different soil treatments namely, T1: BRIS soil, T2: BRIS soil + compost (1:1), T3: BRIS soil + compost (2:1), T4: topsoil, with 5 replications for each treatment. The compost contains 27.5% carbon, 1.7% nitrogen, 1.5% phosphorus, 1.0% potassium, 2.3% calcium, and 1.3% magnesium at pH 6.5. On the other hand, the BRIS soil contains 3.82% carbon, 0.14% nitrogen, 0.1% phosphorus, 0.03% potassium, 0.34% calcium, and 1.01% magnesium at pH 4.5. The BRIS soil and the compost were not in fresh condition therefore biological characters were not measured. The top soil was collected from rice growing field at Ketara, Terengganu Malaysia at the depth of 0–10 cm.

A Malaysian rice variety MR 219-4 was cultivated. Nitrogen (110 kg/ha) as urea in three splits (1/3 as basal + 1/3 at active tillering + 1/3 at late vegetative stage[19]), P_2O_5 (60 kg/ha) as triple super phosphate in one split (full as basal), and K_2O (65 kg/ha) as muriate of potash in two splits (1/2 as basal + 1/2 at reproductive stage) were applied. A compound fertilizer (N: P: K = 12:12:17) was applied twice at 50 and 70 days after sowing at the rate of 250 kg/ha[8]. Irrigation was applied to the pots through a plastic tube attached to the water tank and regulator. The pots were kept without standing water throughout the growing period. Proper agronomic and measurement practices were applied[8].

Measurement of chlorophyll content in leaves

The SPAD-502 chlorophyll meter was used to acquire a rapid estimation of leaf chlorophyll content[20,21]. The measurement was taken on the upper-most collared leaf and five measurements were taken per leaf in each pot. The SPAD-502 readings were measured from 11 AM to 12 PM to avoid moisture on leaves.

Measurement of relative water content

A fresh healthy and unblemished leaf, excluding the apex and collar regions, was collected from each pot. After taking the fresh weight (FW), the samples were placed in Petri dishes containing double distilled water and kept in a moist chamber for 24 h to obtain full turgidity. After 24 h, the samples were removed from the water, blotted dry, and the turgid weight (TW) was recorded. Then the turgid leaf samples were kept in a hot air oven at 60 °C overnight then weight of oven dry (DW) was determined. The relative water content (RWC) was calculated using the following formula[22,23]: $\text{RWC} = (\text{FW} - \text{DW})/(\text{TW} - \text{DW})$.

Measurement of soil pH

The pH of the soil was measured using a portable IQ pH meter as described[8]. The pH electrode was calibrated with appropriate pH buffer solutions before using each time.

Statistical analysis

Data were analysed by ANOVA procedure and differences of mean among treatments were determined by least significant differences test and t-test using Statistical Analysis System software version 6.12 (SAS Inc.) and MS Office Excel 2007 (Microsoft). The differences at $P < 0.05$ were considered significant.

RESULTS AND DISCUSSION

Yield and yield components

To test whether compost sustains rice production on BRIS soil, we measured yield and yield parameters of rice plant grown on BRIS soil and amended of BRIS soil with compost (Table 1). The plant height was not significantly different in all treatments falling in the range of 73–93 cm. The tiller and panicle numbers were significantly increased in the mixture of compost and BRIS soil relative to those of BRIS soil condition. This result indicates that the addition of compost to BRIS soil increases BRIS soil health which increases the number of tillers and panicles per pot. Weight of 1000 seeds was not significantly different regardless of soil condition indicating that the compost did not affect weight of 1000 seeds. This result was consistent with the previous results that different water condition of soil did not affect weight of 1000 seeds[8]. The BRIS soil condition significantly affects total grains and filled grains per panicle. In addition, yield and straw weight (wet basis) was significantly lower in BRIS soil than that of mixture of compost and BRIS soil. This result also indicates that the addition of compost to BRIS soil increases BRIS soil health. The top soil shows similar results as amended of BRIS soil. A large amount of sand (> 90%) and very low physical and chemical characteristics of BRIS soil affect rice yield and yield parameters. Therefore, the yield was significantly decreased under BRIS soil condition (Table 1). Deficiency of nutrients affects

Table 1 Yield and yield parameters of rice plant grown on BRIS and amended of BRIS soil.

Treatment	Plant height (cm)	Tillers /pot	Panicles /pot	1000 seeds weight (g)	Total grains /panicle	Filled grains /panicle	Unfilled grains /panicle	Grain yield (g)	Straw weight (g)
T1	73^{a}	23.5^{b}	17.3^{b}	28.5^{a}	121^{b}	91^{b}	30^{a}	128^{c}	192^{b}
T2	78^{a}	43.5^{a}	32.3^{a}	28.3^{a}	135^{ab}	107^{ab}	28^{a}	271^{ab}	235^{b}
T3	93^{a}	47.3^{a}	41.0^{a}	28.2^{a}	148^{a}	124^{a}	24^{a}	333^{a}	381^{a}
T4	88^{a}	36.8^{a}	33.5^{a}	28.1^{a}	143^{a}	113^{a}	29^{a}	288^{a}	329^{a}

Means with the same letter are not significantly different in column.

rice yield, e.g., potassium deficiency decreased grains production[24]. An application of compost as a soil amendment reduces nitrogen leaching from soil, reduces the amount of commercial nitrogen fertilizer to be applied, and decreases the possibility of nitrate groundwater contamination[25]. It is suggested that the compost might increase BRIS soil health therefore the rice yields were increased.

Compost increases chlorophyll content in rice leaves

To see whether BRIS soil condition affects chlorophyll content, we measured chlorophyll content in rice leaves. The BRIS soil condition significantly decreased chlorophyll content in rice leaves compared to that of rice leaves grown on amended BRIS soil (Fig. 1). In addition, chlorophyll content in leaves of rice plant gradually increased with increasing of plant age regardless of soil condition (data not shown). This result was consistent with the previous result that chlorophyll meter readings generally increase during the growing season up to a maximum level at vegetative stage and then gradually decreased at ripening stage regardless of the atmospheric conditions or plant photosynthesis rate[26]. Our results showed that the BRIS soil condition significantly decreased chlorophyll content in rice leaves which may be due to a nitrogen deficiency[27]. In addition, decreasing chlorophyll content in rice leaf reveals a photosynthetic inactivation[28] which could affect rice yield. In this study we showed that the compost increased chlorophyll content in leaves, suggesting an increase of photosynthesis rate and rice yield.

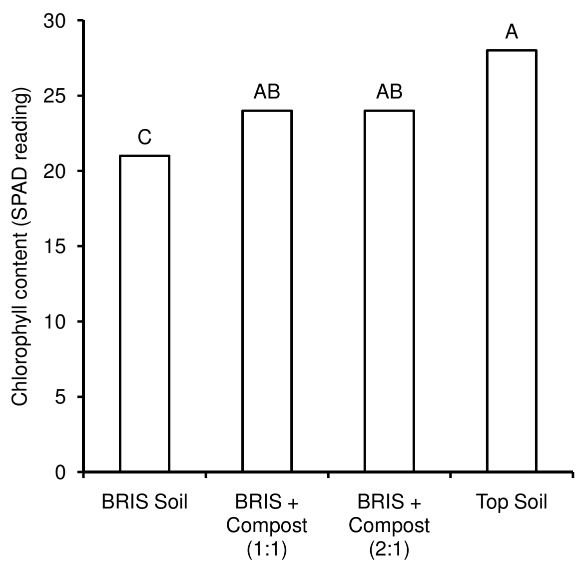

Fig. 1 Chlorophyll contents in leaves of rice plants grown on different soil conditions.

Effect of compost on relative water content in rice leaves

To test whether compost affects RWC in leaves of rice plant, we measured RWC in leaves in weeks 3 and 6. Weekly data of RWC in rice leaves were not significantly different among treatments but the RWC in week 6 was significantly higher than that of week 3. This result indicated that the RWC in rice leaves increased with increasing plant age during vegetative growth (Fig. 2). Consistent with previous results[29], soil conditions did not affect RWC in rice leaves under similar moisture condition in soil. The RWC may depend on the rice variety. A stress condition, high salt condition, increased the RWC in salt tolerant but not in salt susceptible rice plant[22,23].

Effect of compost on soil pH in BRIS soil

The soil pH indicates soil nutrients condition, with most agronomic crops growing well at pH 6.0–7.0. Soil pH was measured in soil from week 1–6 to justify whether addition of compost to BRIS soil affects the pH. Fig. 3 shows that the pH of amended of BRIS soil was significantly increased than that of the BRIS soil, which was consistent with previous results[18]. BRIS soil is highly acidic but the application of compost increases the pH to near neutral condition. This result indicates that the compost increases nutrients availability in BRIS soil. With the availability of

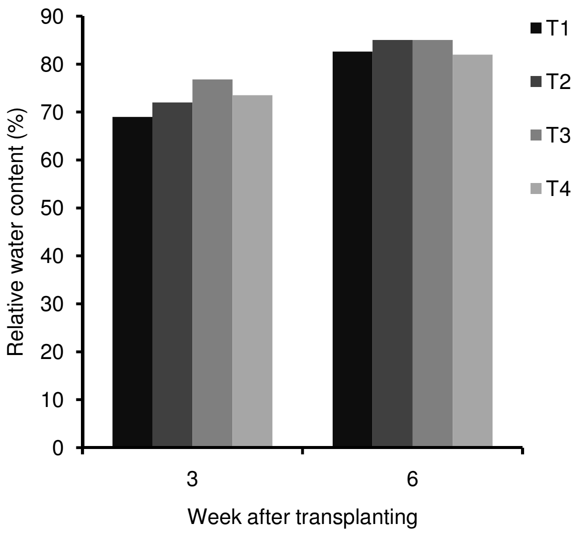

Fig. 2 Relative water contents in leaves of rice plants grown on different soil conditions.

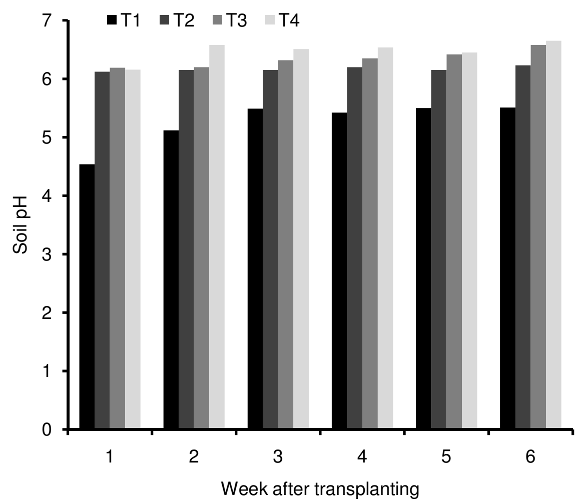

Fig. 3 The effects of compost on pH of BRIS.

nutrients, the activity of micro-organisms responsible for breaking down organic matter and most chemical transformations increases in the soil due to adding compost[30]. Therefore, the pH increment by compost indicates that the availability of essential plant nutrients in BRIS soil was increased. The addition of compost to acid soils reduces or eliminates aluminium or manganese toxicity[31]. Incorporation of compost at rates of 10–20 tons/acre usually increases pH by 0.5–1.0 pH units in acid soils[31] and increases CEC by about 10%[14]. Therefore, the compost might improve the cation exchange capacity in BRIS soils, enabling them to retain nutrients longer so that rice plants can effectively use them. The increment of the cation exchange capacity of BRIS soils by the addition of compost can greatly improve the retention of plant nutrients in the root zone and increase soil pH. This result suggests that the compost improves chemical properties of BRIS soil and sustains rice yield.

In conclusion, rice can be cultivated on BRIS soil after improving the BRIS soil health by the application of compost, but short and long term strategies should be taken.

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REFERENCES

1. Dyson T (1999) World food trends and prospects to 2025. *Proc Natl Acad Sci USA* **96**, 5929–36.
2. International Rice Research Institute (2009) Annual Reports for 2002. Los Baños, Philippines.
3. International Rice Research Institute (2008) Background Paper: The rice crisis: What needs to be done? Los Baños, Philippines.
4. International Rice Research Institute (2008) Where is rice grown? http://irri.org/about-rice/rice-facts/rice-production-and-processing.
5. ASEAN Food Security Information System (2002) The First Technical Meeting Bangkok, Thailand.
6. Toriman MEH, Mokhtar MB, Gasim MB, Aziz NAA (2009) Analysis of the physical characteristics in Coastal Kuala Kemaman, Terengganu. *Res J Earth Sci* **1**, 1–6.
7. Bhuiyan SI, Tuong TP (1995) Water use in rice production: issues, research opportunities and policy implications. Proceeding of the Inter-Center Water Management Workshop, IWMI, Colombo, Sri Lanka.
8. Jahan MS, Khanif YM, Syed Omar SR, Sinniah UR (2004) The effect of different water regimes on yield and bioavailability of phosphorus in rice production in Malaysia. *Malaysian J Soil Sci* **8**, 53–62.
9. Li YH (1999) Theory and Techniques of Water Saving Irrigation. Wuhan Uni. of Hydraul. Electric Engineering Press, Wuhan, China, p 310.
10. Dick WA, McCoy EL (1993) Enhancing soil fertility by addition of compost. In: Hoitink HAJ, Keener HM (eds) Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects. Renaissance Publications. Worthington, OH, pp 622–44.
11. Chitravadivu C, Balakrishnan V, Manikandan J, Elavazhagan T, Jayakumar S (2009) Application of food waste compost on soil microbial population in groundnut cultivated soil, India. *Middle East J Sci Res* **4**, 90–3.

12. Edwards L, Burney JR, Richter G, MacRae AH (2000) Evaluation of compost and straw mulching on soil-loss characteristics in erosion plots of potatoes in Prince Edward Island, Canada. *Agr Ecosyst Environ* **81**, 217–22.
13. Wortmann CS, Shapiro CA (2008) The effects of manure application on soil aggregation. *Nutr Cycl Agroecosys* **80**, 173–80.
14. McConnell DB, Shiralipour A, Smith WH (1993) Compost application improves soil properties. *Biocycle* **34**, 61–3.
15. Gallaher RN, McSorley R (1994) Soil water conservation from management of urban plant debris compost in a farmer's corn field. *Agron Res Rpt* AY-94-02. Agron. Dept., Inst. Food and Agr. Soil, Univ. of Fla., Gainesville, FL.
16. Karlen DL, Stott DE (1994) A framework for evaluating chemical and physical indicators of soil quality. In: Doran J, Coleman D, Bezdicek DF, Stewart BA (eds) Defining soil quality for a sustainable environment. SSSA special publication no. 35. SSSA, Madison, Wis. pp 53–72.
17. Sun H, Larney FJ, Bullock MS (1995) Soil amendments and water-stable aggregation of a desurfaced Dark Brown Chernozem. *Can J Soil Sci* **75**, 319–25.
18. Cox D, Bezdicek D, Fauci M (2001) Effects of compost, coal ash, and straw amendments on restoring the quality of eroded Palouse soil. *Biol Fertil Soils* **33**, 365–72.
19. Wei F, Tao H, Lin S, Bouman BAM, Zhang L, Wang P, Dittert K (2011) Rate and duration of grain filling of aerobic rice HD297 and their influence on grain yield under different growing conditions. *Sci Asia* **37**, 98–104.
20. Richardson AD, Duigan SP, Berlyn GP (2002) An evaluation of noninvasive methods to estimate foliar chlorophyll content. *New Phytol* **153**, 185–94.
21. Wanichananan P, Kirdmanee C, Vutiyano C (2003) Effect of salinity on biochemical and physiological characteristics in correlation to selection of salt tolerance in *Aromatic Rice* (Oryza sativa L.). *Sci Asia* **29**, 333–9.
22. Suriya-arunroj D, Supapoj N, Toojinda T, Vanavichit A (2004) Relative leaf water content as an efficient method for evaluating rice cultivars for tolerance to salt stress. *Sci Asia* **30**, 411–5.
23. Uyprasert S, Toojinda T, Udomprasert N, Tragoonrung S, Vanavichit A (2004) Proline accumulation and rooting patterns in rice in response to water deficit under rainfed lowlands. *Sci Asia* **30**, 301–11.
24. International Potash Institute (2008) Potassium increases grain filling in rice: an example from Indonesia. *e-ifc* Research Findings: No. 16.
25. Shiralipour A, McConnell DB, Smith WH (1992) Compost: Physical and chemical properties of soils as affected by MSW compost application. *Biomass Bioenerg* **3**, 195–211.
26. Ziadi N, Brassard M, Bélanger G, Claessens A, Tremblay N, Cambouris AN, Nolin MC, Parent LE (2008) Chlorophyll measurements and nitrogen nutrition index for the evaluation of corn nitrogen status. *Agron J* **100**, 1264–73.
27. Schlemmer MR, Francis DD, Shanahan JF, Schepers JS (2005) Remotely measuring chlorophyll content in corn leaves with differing nitrogen levels and relative water content. *Agron J* **97**, 106–12.
28. Kurra-Hotta M, Satoh K, Katoh S (1987) Relationship between photosynthesis and chlorophyll content during leaf senescence of rice seedlings. *Plant Cell Physiol* **28**, 1321–9.
29. Jiang Y, Huang B (2002) Protein alterations in tall fescue in response to drought stress and abscisic acid. *Crop Sci* **42**, 202–7.
30. USDA (1998) Soil Quality Indicators: pH. http://soils.usda.gov.
31. Hernando S, Lobo MC, Polo A (1989) Effect of the application of municipal refuse compost on the physical and chemical properties of a soil. *Sci Total Environ* **81/82**, 589–96.