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Research article

Amending inorganic fertilizers with rice straw compost to improve soil nutrients availability, nutrients uptake, and dry matter production of maize (*Zea mays* L.) cultivated on a tropical acid soil

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Abstract: This study was carried out to assess the effect of amending inorganic fertilizers with rice straw (RS) compost in improving the soil nutrients availability, nutrient uptake, and dry matter production of maize cultivated on a tropical acid soil. A pot trial was conducted for 60 days and maize (F1 hybrid sweet corn 801 variety) was used as a test crop. Rice straw compost was applied at rates of 5 t ha^{-1}, 10 t ha^{-1}, 15 t ha^{-1} and 20 t ha^{-1}, respectively. Treatments of amending inorganic fertilizers with RS compost were found to increase soil total N, available P, and exchangeable K at the end of the pot experiment. This was possible because it increases the nutrients availability in the tropical acid soil by reducing NH_3, H_2PO^-, and K^+ loss through volatilisation, leaching and denitrification. The soil pH and the soil EC also significantly increased with the presence of RS compost. Dry weight of maize plants (leaf and stem) and higher N, P, and K uptake in leaf, stem, and root of maize were observed under treatments amended with RS compost. An application rate of 15–20 t ha^{-1} of RS compost together with 130 kg ha^{-1} urea, 200 kg ha^{-1} Christmas Island rock phosphate, and 67 kg ha^{-1} muriate of potash are recommended to improve the soil NPK contents and growth of *Zea mays* in acidic soil.

Keywords: F1 hybrid sweet corn 801; organic amendment; pot trial; soil fertility; plant nutrients

1. Introduction

In most acidic soil, nitrogen (N) deficiency happens due to the ammonia (NH_3) volatilization and leaching of highly mobile ammonium (NH_4^+) as well as nitrate ($NO3^-$) which make them less available for plant uptake [1]. Low phosphorus (P) availability in acidic soil is usually due to fixation of P with the abundant aluminium (Al) and iron (Fe) in the soil. The reaction between soluble P ions and Al as well as Fe causes the formation of insoluble phosphate [2]. Potassium (K) is highly vulnerable to loss by leaching [3]. The leaching of K is a major problem in sandy and silt soils as sandy and silt soil have a low cation exchange capacity (CEC) and do not have a large K^+ fixing capacity [4].

Since N, P, and K losses are progressively increased, most farmers tend to supply higher amount of fertilizers in order to maximize the production of the crops. This excessive application of fertilizers will cause the accumulation of excessive fertilizers in the farm and result in severe environmental problems. The excessive NH_3 and oxides of N in the atmosphere caused by volatilization and denitrification from soils may cause detrimental effects from human health. Liming in acid soils can improve the P availability by increasing the soil pH. However, over liming will again induce P deficiency due to fixation of P with calcium (Ca). High level of K can bring a negative impact on the soil pH, soil structure deterioration, and increasing the feature for acid irrigation [5].

In recent decades, compost application is one of the major interesting research subjects due to the concern to waste management. For instance, agricultural wastes such as fruits peels, soy beans residues, banana residues, and sago wastes which are easily available and contain high N, P, and K can be used to produce a stable fertilizer resource by composting with earthworm, animal manure, and poultry litter in order to reduce environmental pollution caused by agricultural wastes [6,7]. Therefore, the abundance of agricultural waste such as rice straw (RS) in paddy industry can be effectively transformed and converted into organic fertilizer via composting process. Through composting, a better nutrient balance output can be produced, relatively cost-saving, and able to serve as an alternative to produce a stable end-product.

Compost has high cation exchange capacity (CEC) as well as negative charges in soil will increase the retention of positively charged ions such as NH_4^+. Hence, all the nutrients will be retained and utilized effectively. Moreover, Laird et al. [8] proved that organic amendment could contribute to the reduction of total N as well as total dissolved P losses by 11% and 69%, respectively. Other study done by Yao et al. [9] showed that organic amendment could contribute to the reduction of nitrate as well as ammonia by 34% and 14%, respectively. Composts contain organic form of N and K which undergoes slow mineralization in the soil to convert the organic nutrient to inorganic nutrient available for plant uptake. Compost also acts as slow release fertilizer as the released of N is relatively slow at 1–3% of total N/year [10]. This will in turn prevent the nutrient leaching causing eutrophication and reduce the denitrification of nutrient. Besides, compost also improves the soil fertility and nutrient replenishment which contribute to revegetation. According to Beesley et al. [11], application of organic amendment has played an important role in remediation, revegetation and restoration of contaminated soils.

However, there is a dearth of information on the use of compost from agricultural wastes with a large surface area and high degree of negative charges which could increase the soil N, P, and K availability, improve nutrients uptake and dry matter production of plants cultivated on tropical acid soil. Thus, the objective of this study was to assess the effect of amending inorganic fertilizers with RS compost in improving the soil N, P, and K availability, nutrients uptake, and dry matter production of maize cultivated on tropical acid soil.

2. Materials and methods

2.1. Soil sampling and characterization

Soil samples were sampled at 0−40 cm from a grassland which has not been cultivated since 2007. The sampling area was 50 m × 50 m from which soil samples were randomly taken. This soil type (Rengam Series, *Typic Paleudult*) was selected because it is commonly cultivated with different crops in Kelantan, Malaysia although the soil is characterized by high P-fixing due to high Al and Fe contents [12]. They were bulked, air dried, crushed and sieved to pass through a 2 mm sieve for characterization and 5 mm sieve for pot experiment.

Before the commencement of pot experiment, soil samples were analyzed for soil bulk density using a core-ring method [13]. A hydrometer was used to determine the soil texture [14]. A digital pH and EC meter was used to determine the soil pH and electrical conductivity (EC) in a 1:2.5 soil-water ratio [15]. Loss-on-ignition method as described by Chefetz et al. [16] was used to estimate the soil total organic matter and the soil total C was derived from the total organic matter by using a conversion factor of 0.58 [13]. Soil total N was determined by using Kjeldahl method [13]. Mehlich No. 1 double acid was used to extract the soil available P [13,17] and the estimation of soil available P concentration was done via molybdenum blue method [18] by using UV-spectrophotometer at 882 nm. Exchangeable cations (K, Ca, Mg, Fe, and Zn) were extracted by using Mehlich No.1 double acid and the contents of exchangeable cations were determined using Atomic Absorption Spectrometer (AAS) [13]. Soil exchangeable acidity and exchangeable Al were extracted using KCl and estimated by titration method [19].

2.2. Compost production and characterization

The RS compost used in this study was produced by composting RS with goat manure slurry in our previous study [20]. The RS compost was analyzed for pH, EC, total organic matter and total C by using the aforementioned procedures in Soil Sampling and Characterization section. Total N, P, K, Ca, Mg, Na, Zn and Fe contents in the compost were extracted by using dry ashing method as described by Cottenie [21]. The concentrations of total cations were eventually determined by AAS while the molybdenum blue method was used to determine the concentration of total P. The C/N and C/P ratios of RS compost were calculated by using the respective total C, N and P content.

2.3. Pot experiment

The pot experiment was conducted in a netted house located at Universiti Malaysia Kelantan Jeli Campus, Malaysia. The test crop used in this study was F1 hybrid sweet corn 801 variety. Pots (22 cm in height, 30 cm in width and 30 cm in diameter) were filled with 7 kg of soil (from the 5 mm bulked soil sample). The selected physico-chemical properties of Rengam soil series (Typic Paleudult, clayey, kaolinitic, isohyperthermic) soil used in the present study are shown in Table 1. The texture of the soil was a sandy clay loam with a bulk density of 1.03 g m^{-3}. Generally, the soil was acidic (pH of 5.19) and had low concentration of available P (0.81 mg/kg). The soil also showed relatively high concentrations of Al and Fe due to low soil pH (Table 1).

The pH of RS compost was 7.55. The C/N and C/P ratios of RS compost were 19.92 and 125.38, respectively (Table 2). These ratios suggest net mineralization of the organic amendments [27]. The RS compost also contained relatively high concentration of exchangeable cations especially K (8.71%), Ca (0.55%), Mg (0.345) and Na (10.6%) (Table 2).

Table 1. Selected physico-chemical properties of soil.

Property	Value Obtained	Property	Value Obtained
Bulk density (g cm^{-3})	1.03	Available P (mg/kg)	0.81
Soil texture	Sand: 75%	Exchangeable acidity (cmol kg^{-1})	0.57
	Clay: 24%	Exchangeable Al (cmol kg^{-1})	1.23
	Silt: 1% (Sandy clay loam)	Exchangeable K (mg/kg)	180.16
pH (water)	5.19	Exchangeable Ca (mg/kg))	959.2
Total organic matter (%)	3.36	Exchangeable Mg (mg/kg)	1,774.13
Total C (%)	1.95	Exchangeable Fe (mg/kg)	186.44
Total N (%)	0.03	Exchangeable Zn (mg/kg)	0.85

Table 2. Selected chemical properties of rice straw compost.

Property	Rice straw compost
pH	7.55
Electrical conductivity (dS m^{-1})	1.53
Total organic matter (%)	73.53
Total C (%)	42.63
Total N (%)	2.14
Total P (%)	0.34
C/N ratio	19.92
C/P ratio	125.38
Total K (%)	8.71
Total Ca (%)	0.55
Total Mg (%)	0.345
Total Na (%)	10.6
Total Zn (µg/g)	54.2
Total Cu (µg/g)	8
Total Fe (µg/g)	1,362.40

The N, P, and K inorganic fertilizers were applied during the pot experiment to ensure the optimum growth of the maize crop Urea (46% N), Christmas Island rock phosphate (CIRP) (32% P_2O_5) and Muriate of Potash (MOP) (60% K_2O) were applied at 60 kg N ha^{-1} (130 kg ha^{-1} urea), 60 kg P_2O_5 ha^{-1} (200 kg ha^{-1} CIRP), and 40 kg K_2O ha^{-1} (67 kg ha^{-1} MOP). These rates based on the recommendation of MARDI [22]. Based on the recommendations, the rated was scaled down to 5 g of urea, 7.7 g of CIRP and 2.58 g of MOP in 7 kg of soil per pot, respectively. The fertilizers were applied in two equal splits at 10 and 28 days after sowing (DAS) by surface applied [23]. The RS compost were applied at rates of 5 t ha^{-1}, 10 t ha^{-1}, 15 t ha^{-1} and 20 t ha^{-1}, respectively. These rates follow the standard recommendation for maize (*Zea mays* L.) cultivation by John et al. [24].

The soil and RS compost were thoroughly mixed. The maize seeds were soaked in water for 24 hours before sowing to ensure a good germination and plant establishment [23]. Then, the seeds were sown in planting holes (1 seed per hole) after which the holes were partially covered with loose soil. Three seeds were sown per pot and later they were thinned to one at 7 DAS. The pot experiment was carried out in a completely randomized design (CRD) with three replications. The volume of water used for each pot was maintained by based on field capacity 50–60%. Plants were checked regularly for possible disease and pest attack during pot experiment. The plants were monitored up to tasseling stage (60 DAS) before harvest. This is because tasseling stage is the maximum growth stage of the plant can be achieved before it goes to productive stage [25]. Treatments evaluated in the pot experiment were as follows:

Table 3. List of treatments evaluated in the pot experiment.

Treatment	Description
T0	Soil only (Serves as a negative control, without any application of urea, CIRP, MOP, and RS compost)
T1	Soil + 130 kg ha^{-1} urea + 200 kg ha^{-1} CIRP + 67 kg ha^{-1} MOP [Serves as a positive control, application of chemical fertilizers (urea, CIRP, and MOP) only without any RS compost]
T2	Soil + 130 kg ha^{-1} urea + 200 kg ha^{-1} CIRP + 67 kg ha^{-1} MOP + 5 t ha^{-1} RS compost
T3	Soil + 130 kg ha^{-1} urea + 200 kg ha^{-1} CIRP + 67 kg ha^{-1} MOP + 10 t ha^{-1} RS compost
T4	Soil + 130 kg ha^{-1} urea + 200 kg ha^{-1} CIRP + 67 kg ha^{-1} MOP + 15 t ha^{-1} RS compost
T5	Soil + 130 kg ha^{-1} urea + 200 kg ha^{-1} CIRP + 67 kg ha^{-1} MOP + 20 t ha^{-1} RS compost

Note: Application of chemical fertilizers (urea, CIRP, and MOP) with different rates of RS compost to evaluate the potential of RS compost in improving the soil P availability provided by CIRP.

At tasseling (60 DAS), the soil samples from pots were collected, air dried, crushed and sieved to pass through a 2 mm sieve. Afterwards, the soil samples were analysed for pH, EC, exchangeable acidity and Al, total N, total C, available P and exchangeable cations (K, Ca, Mg, Na and Fe) by using aforementioned procedures in previous section. Then, the above ground parts of the plants were harvested and partitioned into leaves and stems while the remaining roots in the soil was collected by washing the soil from the root using tap water followed with distilled water [12]. The plant parts were dried in oven at 60 °C until a constant weight was achieved, and their dry weight were determined using a digital balance [26]. Each plant parts were ground and determined for total N, P, K concentrations. The single dry ashing method [21] was used to extract P and K in the plant tissues (leaf, stem, and root). The filtrates were analysed for K by using ASS. Meanwhile, P was determined using molybdenum blue colorimetric method while total N was determined by using Kjeldahl method. All nutrients estimated were reported on elemental percentage basis. The concentrations of N, P, and K in leaf, stem, and root were multiplied by the respective dry weight of the plants parts to obtain the amount of N, P, and K uptake by the maize plants.

$$\text{Uptake} = \text{Concentration} \times \text{Dry weight (g)}$$

2.4. Statistics analysis

Statistical analysis for all the data was performed using SPSS software version 24.0 (SPSS Inc, US). The effects of different rates of RS compost additions on all the replicated measurement were tested via one-way analysis of variance (ANOVA). Significant differences among treatment means were separated using the Tukey's HSD test. All result was considered significant at $P \leq 0.05$.

3. Results and discussions

3.1. Effects of rice straw compost on selected soil chemical properties and nutrients availability at 60 DAS

At 60 DAS, the soil pH of the treatments applied with RS compost (T2, T3, T4, and T5) were significantly increased compared to treatments without RS compost (T0 and T1) (Table 4). The significant increase in soil pH was mainly due to the initial high pH of the RS compost. Highly decomposed RS compost consists of humic and fulvic acids. These acids possessed a carboxyl group which allowed it to consume H^+ as well as Al [28]. Thus, this might help in increasing the soil pH and decreased the Al concentration. According to Ch'ng et al. [12], basic cations like Na, Ca, K, and Mg released from the RS compost have caused the exchanged of protons between the RS compost and the soil, thus increased the soil pH. In this study, T1 had a higher pH compared to T0 due to types as well as different composition of fertilizer which resulted in the increase in soil pH [29]. In addition, RS compost was high in basic cations contents (K, Ca, Mg, and Na) (Table 2). The release of these cations from RS compost caused the exchange of protons between the RS and soil, hence increased the soil pH [12]. Meanwhile, the increase of the soil pH for soil and chemical P fertilizer only (T1) after the pot experiment could be due to the dissolution of Ca and Mg from the applied CIRP which contained high Ca concentration. Similar observation was observed in a study by Ch'ng et al. [23] and Sanusi et al. [30], whereby treatments amended with organic amendments significantly increased soil pH at the end of pot trial compared with non-organic amendments due to the higher pH of organic inputs.

The EC value increased in treatments applied with RS compost (T2, T3, T4, and T5) compared to treatments without RS compost (T0 and T1) at 60 DAS (Table 3). This was due to the dissolution of Na from the RS compost [31]. Treatments with higher rate of RS compost (T3, T4, and T5) significantly increased the total organic matter in the soil at 60 DAS compared to T0, T1, and T2 (Table 4). However, there was no significant difference between T3, T4, and T5 in terms of soil total organic matter at 60 DAS. The highest total organic matter in soil after 60 DAS was T5 (13.33%), and this was due to highest rate of RS compost application, which in return contributed more organic matter meanwhile the lowest total organic matter was found for T0 due to without any addition of organic amendment. The soil total C also increased as the soil total organic matter increased (Table 4).

Exchangeable acidity and Al of soil were affected significantly ($P \leq 0.05$) due to application of RS compost (Table 4). The soil applied with RS compost reduced the exchangeable acidity and Al level significantly with increasing rates of RS compost compared to without RS compost amendment (T0 and T1). The significantly reduction of exchangeable acidity and Al concentrations in T2, T3, T4, and T5 was due to the increase of soil pH. In addition, the reduction of exchangeable Al was due to the adsorption of Al by RS compost complexion sites, (Fleming et al., 2013). Furthermore, the finding is consistent with findings of previous study by Ch'ng et al. [12,23,32], in which the organic amendments resulted in lowering the exchangeable acidity and exchangeable Al level due to increase in soil pH.

The total N in the soil was significantly increased with treatments amended with RS compost at 60 DAS (Table 4). The significant increase of soil total N might be due to mineralization of the RS compost [33] and retention of NH_4^+ and NO_3^- from being lost through volatilization and leaching. This finding is consistent with findings of the previous studies by Yazdanpanah et al. [34], who concluded that the increased in total N in soil was due to treatments with organic amendments had stronger affinity for NH_4^+ and NO_3^-. Besides, the inherent of total N in RS compost also might provide the increment of total N in soil. This observation is also corresponding with that study of Latifah et al. [33] who mentioned that organic amendment serves as source of microorganism to decompose organic N in soil and hence increase the total N in soil.

Soil applied with RS compost significantly improved the soil available P compared to treatments of the control (T0) and chemical P fertilizer only (T1) (Table 4). Treatment with highest rate of RS compost application (T5) showed the highest soil available P due to more inherent of P contents in RS compost. As a result of the increase in the soil pH at 60 DAS, the negative charges on the surface area of RS compost increased, thus the increased affinity for Al and Fe ions instead of P. This led to the increase in the soil available P concentrations [12,23,32].

From Table 4, it was apparent that there was a significant increase in exchangeable cations (K, Ca, Mg, and Na) under the treatments applied with RS compost and CIRP (T2, T3, T4, and T5) compared to treatments without RS compost (T0 and T1). The significant highest contents of K, Ca, Mg and Na were observed in T5 (20 t ha^{-1} of RS compost). The increase of exchangeable cations was possibly due to the dissolution from the RS compost, and this caused a liming effect in the soils which in turn reduced the concentrations of Al and Fe. Hence, P that were initially bound by the Al and Fe were freed from the soil [35]. On the other hand, the exchangeable Fe of treatments applied with higher rates of RS compost (T3, T4, and T5) significantly lower than T2 and treatments of without RS compost (T0 and T1) (Table 5). This was due to a very strong affinity of metals for organic complexation sites and the increased of CEC due to the addition of RS compost [36]. On the other hand, T1 had the highest exchangeable Fe due to CIRP released Fe into the soil solution [32].

Table 4. Effects of rice straw compost on selected soil chemical properties in Rengam acidic soil at 60 DAS of pot experiment.

Treatments	pH (water)	EC (dS m^{-1})	Total organic matter (%)	Total C	Exchangeable acidity (cmol kg^{-1})	Exchangeable Al	Total N (%)	Available P ppm
T0	5.28 ± 0.06 d	0.12 ± 0.02 d	7.47 ± 0.09 c	4.33 ± 0.05 b	1.13 ± 0.03 a	0.72 ± 0.06 b	0.06 ± 0.00 c	14.59 ± 0.15 f
T1	6.12 ± 0.01 c	0.30 ± 0.03 c	7.63 ± 0.09 c	4.43 ± 0.05 b	0.98 ± 0.01 a	0.99 ± 0.12 a	0.06 ± 0.00 c	29.61 ± 0.52 e
RST2	6.32 ± 0.01 b	0.48 ± 0.04 b	9.60 ± 0.23 b	4.67 ± 0.91 b	0.67 ± 0.07 b	0.64 ± 0.06 b	0.08 ± 0.00 b	62.65 ± 0.13 d
RST3	6.46 ± 0.01 b	0.59 ± 0.02 b	11.07 ± 0.98 b	6.42 ± 0.57 a	0.46 ± 0.02 c	0.42 ± 0.06 c	0.08 ± 0.00 b	282.73 ± 1.07 c
RST4	6.60 ± 0.02 a	0.76 ± 0.00 a	11.27 ± 1.00 b	6.53 ± 0.58 a	0.17 ± 0.01 d	0.32 ± 0.07 c	0.09 ± 0.01 b	305.54 ± 0.92 b
RST5	6.63 ± 0.03 a	0.76 ± 0.01 a	13.33 ± 0.24 a	7.73 ± 0.14 a	0.10 ± 0.01 d	0.21 ± 0.04 c	0.11 ± 0.00 a	370.87 ± 0.56 a

Note: Mean values within column with different letter(s) indicate significant difference between treatments by Tukey's test at $P \leq 0.05$. Columns represent the mean values ± SE.

Table 5. Effects of rice straw compost on selected soil exchangeable cations in Rengam acidic soil at 60 DAS of pot experiment.

Treatments	Exchangeable K mg/L	Exchangeable Ca	Exchangeable Mg	Exchangeable Na	Exchangeable Fe
T0	654.25 ± 0.72 f	1,013.00 ± 1.00 f	2,179.50 ± 0.87 f	333.00 ± 0.89 f	359.00 ± 0.69 b
T1	786.00 ± 0.12 e	1,329.00 ± 0.58 e	2,728.30 ± 0.89 e	693.00 ± 1.13 e	524.00 ± 0.72 a
RST2	1,255.00 ± 0.55 d	1,565.67 ± 0.55 d	4,319.33 ± 0.85 d	1,089.00 ± 0.50 d	358.33 ± 0.35 b
RST3	1,526.67 ± 0.67 c	1,709.67 ± 0.88 c	5,792.00 ± 1.63 c	1,134.00 ± 0.35 c	220.67 ± 0.44 c
RST4	3,672.00 ± 0.58 b	2,779.67 ± 0.34 b	9,074.67 ± 1.78 b	1,766.00 ± 1.73 b	204.34 ± 0.65 d
RST5	4,479.33 ± 0.41 a	3,508.33 ± 0.34 a	9,456.00 ± 1.07 a	2,352.50 ± 0.06 a	148.67 ± 0.34 e

Note: Mean values within column with different letter(s) indicate significant difference between treatments by Tukey's test at $P \leq 0.05$. Columns represent the mean values ± SE.

3.2. Effects of rice straw compost on maize dry matter production and nutrients uptake

Dry weight of hybrid sweet corn 801 (leaf, stem, and root) affected by the application of RS compost were summarized in Table 5. At 60 DAS the differences between treatments without RS compost (T0 and T1) and treatments with RS compost (T2, T3, T4, and T5) were statistically significant with respect to the leaf and stems' dry weight. Treatments T4 and T5 produced the largest dry weight. The root's dry weight measured at 60 DAS increased significantly T2, T3, T4, and T5) compared to T0 and T1. The T3, T4, and T5 showed the most pronounced effect (Table 6). As for the overall dry weight T4 and T5 showed the most pronounced effect among the treatments. The increased in dry matter production of maize plant could be due to the increased in number of leaves [37]. Number of leaves increased with the amount of RS compost input which indirectly influencing the increase in dry weight of the maize.

Table 6. Effects of rice straw compost on dry weight of *Zea mays* L. F1 hybrid sweet corn 801 variety at 60 DAS of pot experiment.

Treatment	Dry weight of plant (g plant^{-1})			
	Leaf	Stem	Root	Total
T0	1.22 ± 0.14 d	0.85 ± 0.27 c	1.21 ± 0.10 b	3.29 ± 0.43 c
T1	0.75 ± 0.28 d	0.66 ± 0.24 c	0.16 ± 0.02 c	1.57 ± 0.52 c
T2	6.68 ± 0.70 c	6.38 ± 1.55 b	1.92 ± 0.35 b	14.98 ± 1.94 b
T3	13.08 ± 0.65 b	11.20 ± 1.75 a	5.37 ± 1.88 a	29.65 ± 2.99 b
T4	18.30 ± 0.91 a	12.46 ± 2.19 a	5.51 ± 2.21 a	36.26 ± 3.71 a
T5	18.66 ± 3.27 a	15.70 ± 6.90 a	5.75 ± 2.18 a	40.12 ± 11.93 a

Note: Mean values within column with different letter(s) indicate significant difference between treatments by Tukey's test at $P \leq 0.05$. Columns represent the mean values ± SE.

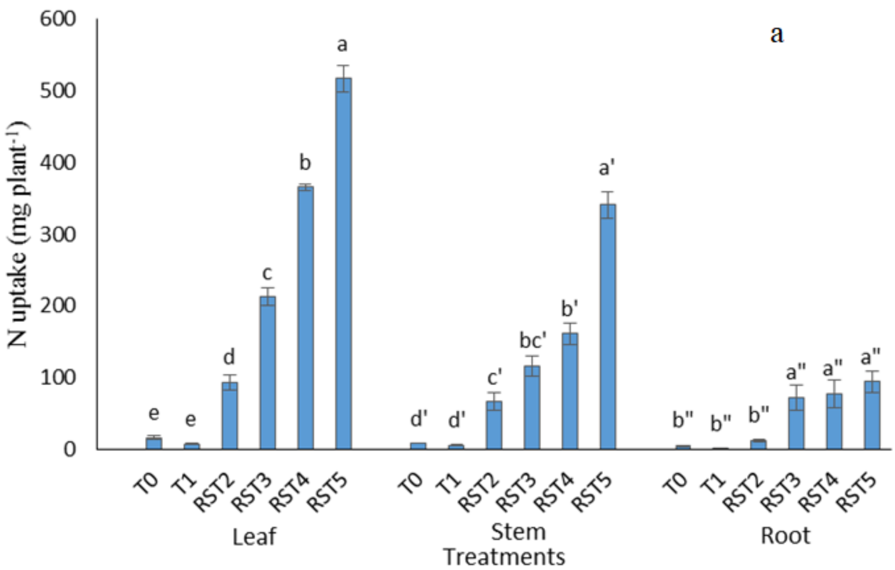
The effect of treatments on the plant nutrient concentration in F1 hybrid sweet corn 801 variety was showed in Table 6. The concentration of N, P, and K in plant leaves, stems and roots were relatively higher in treatments applied with RS compost at 60 DAS (Table 7).

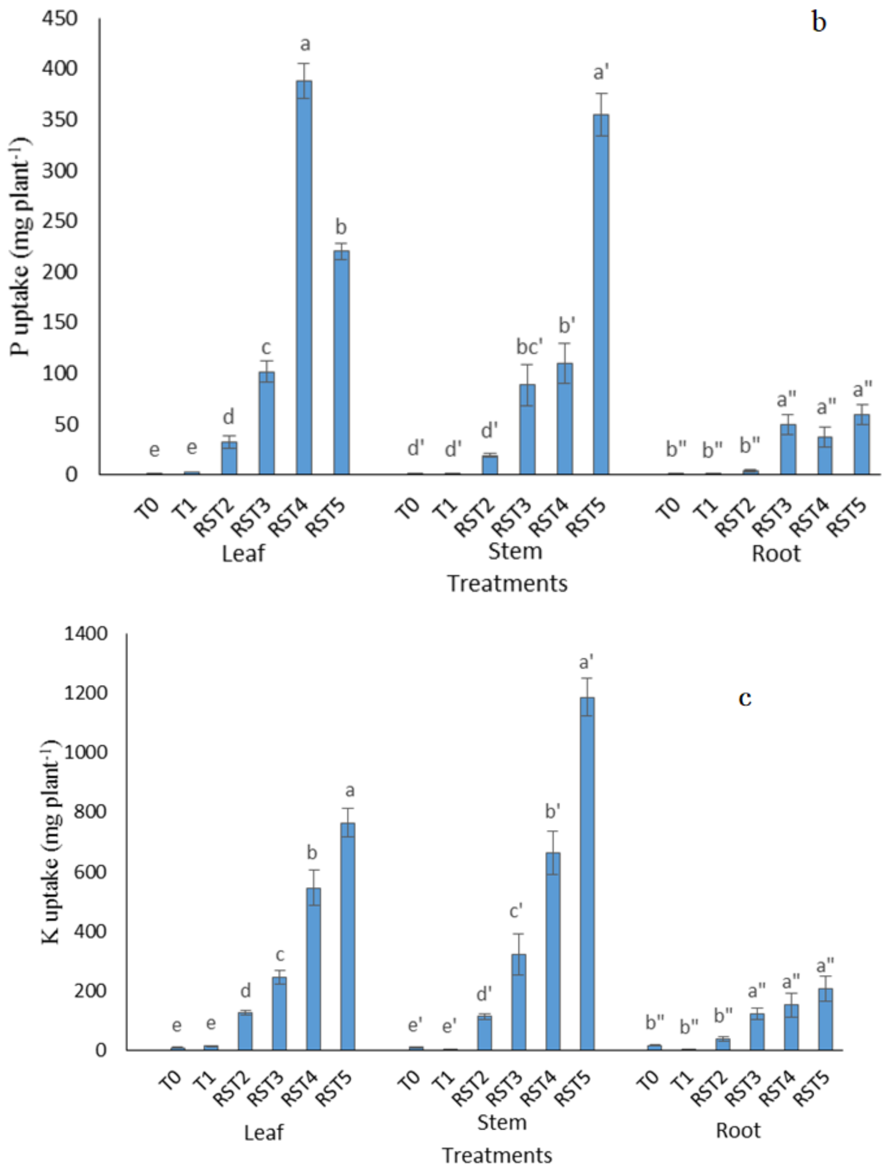
The treatments applied with RS compost (T2, T3, T4, and T5) showed an increased in the N, P, and K uptake for each plant parts (leaf, stem and root) compared to T0 and T1 at 60 DAS (Figure 1). The increase in the concentration of primary nutrients was due to the microbial mediated mineralization causing an increased in available nutrients for plant uptake [38]. According to Liu et al. [39], RS compost can affect total nutrient and plant uptake by increasing the soil pH. Reactive groups on the surface of RS compost such as carboxyl, phenoxyl, as well as hydroxyl react with trace elements (Al and Fe) to form a stable complex. Altering the metals blocking capacity caused by the Al and Fe might be useful in reducing the Al and Fe bioavailability [40]. This results in the increase in soil pH and caused the release of more available P in the soil for plant uptake. The T1 had the lowest plant nutrient uptake in plants and this might due to the drastic immobilisation of chemical fertilizer during plant growth [41]. This immobilisation will reduce the plant uptake and caused the plant to be stunted growth. Unlike T1, RS compost in T2, T3, T4, and T5 with slow released properties allowed nutrient retention in soil for plant uptake. This might stimulate the alleviation of significantly immobilisation of inorganic fertilizer.

Table 7. Effects of rice straw compost on plant nutrient concentrations of *Zea mays* L. F1 hybrid sweet corn 801 variety at 60 DAS of pot experiment.

Treatment	N (%)	P	K	Ca	Mg
Leaf					
T0	1.35 ±0.12 c	0.10 ±0.05 d	0.62 ±0.04 e	0.08 ±0.02 d	0.04 ±0.01 c
T1	0.61 ±0.17 d	0.26 ±0.03 d	1.28 ±0.16 d	0.15 ±0.01 c	0.01 ±0.003 d
T2	1.40 ±0.00 c	0.48 ±0.04 c	1.87 ±0.08 c	0.18 ±0.003 bc	0.07 ±0.002 b
T3	1.63 ±0.12 c	0.78 ±0.13 c	1.86 ±0.10 c	0.24 ±0.01 ab	0.09 ±0.003 b
T4	2.01 ±0.09 b	2.13 ±0.41 a	2.96 ±0.17 b	0.21 ±0.01 bc	0.12 ±0.01 a
T5	2.75 ±0.05 a	1.26 ±0.22 b	4.17 ±0.52 a	0.28 ±0.02 a	0.15 ±0.01 a
Stem					
T0	0.75 ±0.05 c	0.15 ±0.02 d	0.94 ±0.24 cd	0.10 ±0.03 c	0.02 ±0.01 d
T1	0.65 ±0.12 c	0.08 ±0.02 e	0.29 ±0.11 d	0.03 ±0.01 d	0.01 ±0.003 d
T2	0.84 ±0.08 b	0.32 ±0.07 c	1.45 ±0.04 c	0.15 ±0.01 bc	0.09 ±0.01 c
T3	0.84 ±0.21 b	0.76 ±0.12 b	2.77 ±0.30 b	0.21 ±0.01 ab	0.10 ±0.01 bc
T4	1.31 ±0.05 ab	0.85 ±0.08 b	5.29 ±0.08 a	0.21 ±0.01 ab	0.14 ±0.01 ab
T5	1.68 ±0.14 a	1.80 ±0.23 a	5.70 ±0.32 a	0.23 ±0.01 a	0.15 ±0.01 a
Root					
T0	0.51 ±0.12 b	0.07 ±0.02 b	1.22 ±0.18 cd	0.15 ±0.01 c	0.04 ±0.01 c
T1	0.33 ±0.05 b	0.04 ±0.01 b	0.62 ±0.04 d	0.08 ±0.02 d	0.01 ±0.003 d
T2	0.65 ±0.05 b	0.23 ±0.01 b	1.87 ±0.08 bc	0.18 ±0.003 bc	0.06 ±0.002 c
T3	1.07 ±0.05 a	0.77 ±0.03 a	1.86 ±0.10 bc	0.28 ±0.02 a	0.10 ±0.004 b
T4	1.17 ±0.05 a	0.69 ±0.14 a	2.21 ±0.22 b	0.20 ±0.01 bc	0.12 ±0.01 b
T5	1.35 ±0.05 a	0.87 ±0.05 a	2.96 ±0.17 a	0.26 ±0.02 ab	0.15 ±0.01 a

Note: Mean values within column with different letter(s) indicate significant difference between treatments by Tukey's test at P ≤ 0.05. Columns represent the mean values ±SE.





Note: Means with different letter (s) indicate significant between treatments by Tukey's test at $P \leq 0.05$. Bars represent the mean values ± SE.

Figure 1. Effect of rice straw compost on N, P, and K uptake in leaf, stem, and root of *Zea mays* L. FI hybrid sweet corn 801 variety at 60 DAS of pot experiment.

4. Conclusions

In this study, amending inorganic fertilizers with RS compost was found to increase soil total N, available P, and exchangeable K at the end of the pot experiment. This was possible because it increases the nutrients availability in the tropical acid soil by reducing NH_3, H_2PO^-, and K^+ loss through volatilisation, leaching and denitrification. The soil pH and the soil EC also significantly increased with the presence of RS compost. Besides, amending inorganic fertilizers with RS compost also significantly improved the dry matter production, N, P, and K uptake in leaf, stem and root of the maize plants compared to soil only and treatment with application of inorganic fertilizers only. As a summary, an application rate of 15–20 t ha^{-1} of RS compost is recommended to improve the soil NPK contents and growth of *Zea mays* in acidic soil.

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Conflict of interest

The authors declare no conflict of interest.

References

1. Park SC (2009) Economic analysis on animal manure; static and dynamic approach, Cox Non-Nested Test, and optimal nitrogen rates for grasses, 1–12.
2. Bryan H, E Jason (2005) Phosphorus availability with alkaline/calcareous soil. Western Nutrient Management Conference 6, Salt Lake City, UT.
3. Mohsen J (2007) Site-specific potassium application based on the fertilizer potassium availability index of soil, Springer Science + Business Media, LLC, 199–211.
4. Jalali M, Rowell DL (2003) The role of calcite and gypsum in the leaching of potassium in a sandy soil. *Exp Agric* 39: 379–394.
5. Swapna M, Bhandarkar SE (2015) A review on effect of various contaminants on soil productivity and quality. *Int J Sci Eng Res* 6: 304–306.
6. Petrus AC, Ahmed OH, Muhamad AMN, et al. (2010) Effect of K-N-humates on dry matter production and nutrient use efficiency of maize in Sarawak, Malaysia. *Sci World J* 10: 1282–1292.
7. Choy SY, Wang K, Qi W, et al. (2015) Co-composting of horticultural waste with fruit peels, food waste, and soybean residues. *Environ Technol* 36: 1448–1456.
8. Laird D, Fleming p, Wang B (2010) Biochar impact on nutrient leaching from a Midwestern agricultural soil. *Geoderma* 158: 436–442.
9. Yao Y, Gao B, Zhang M, et al. (2012) Effect of biochar amendment on sorption and leaching of nitrate, ammonium, and phosphate in a sandy soil. *Chemosphere* 89: 1467–1471.
10. Ch'ng HY, Ahmed OH, Majid NMA (2016) Minimizing phosphorus sorption and leaching in a tropical acid soil using Egypt rock phosphate with organic amendments. *Philippine Agric Sci* 99: 176–185.
11. Beesley L, Moreno JE, Gomez EJL, et al. (2011) A review of biochars' potential role in the remediation, revegetation and restoration of contaminated soils. *Environ Pollut* 159: 3269–3282.
12. Ch'ng HY, Ahmed OH, Majid NMA, et al. (2019) Improving soil phosphorus availability and yield of *Zea mays* L. using biochar and compost derived from agro-industrial wastes. *Italian J Agr* 14: 34–42.
13. Tan KH (2005) Soil and plant test. In: Tan KN, Eds., Soil sampling, preparation, and analysis 2Eds., 98–134. Boca Raton, USA: CRC Press, Taylor & Francis Group.
14. Bouyoucos GJ (1962) Hydrometer meter improved for making particle size analysis of soils. *Agron J* 54: 464–465.
15. Peech HM (1965) Hydrogen-ion activity. In: Black CA, Evans DD, Ensminger LE, et al., Eds., Methods of soil analysis Part 2 chemical and microbiological properties, 914–926, Madison, WI: American Society of Agronomy.

16. Chefetz B, Hatcher PH, Hadar Y, et al. (1996) Chemical and biological characterization of organic matter during composting of municipal solid waste. *J Environ Qual* 25: 776–785.
17. Mehlich A (1953) Determination of P, Ca, Mg, K, Na and NH_4 by the North Carolina Soil Testing Laboratory. Releigh, NC: North Carolina State University Soil Test Division.
18. Murphy J, Riley JP (1962) A modified single solution method for the determination of phosphate in natural waters. *Anal Chim Act* 27: 31–36.
19. Rowell DL (1994) Soil acidity and alkalinity. In: Rowell DL, Soil science: Methods & applications, 153–174, Harlow, UK: Longman Scientific & Technical, Wiley.
20. Sanusi S, Ch'ng HY, Othman S (2018) Production, characterization and phytotoxicity evaluation of compost produced from rice straw and goat manure slurry. *Int J Appl Res Technol* 7: 21–29.
21. Cottenie A (1980) Soil testing and plant testing as a basis of fertilizer recommendation. *FAO Soils Bul* 38: 70–73.
22. Malaysia Agricultural Research and Development Institute (MARDI) (1993) Jagung Manis Baru (New Sweet Corn): Masmadu. Kuala Lumpur, Malaysia: MARDI.
23. Ch'ng HY, Ahmed OH, Majid NMA (2015) Improving phosphorus availability, nutrient uptake and dry matter production of *Zea mays* L. on a tropical acid soil using poultry manure biochar and pineapple leaves compost. *Exp Agric* 52: 447–465.
24. John NM, Uwah DF, Iren OB, et al. (2013) Changes in maize (*Zea mays* L.) performance and nutrients content with the application of poultry manure, municipal solid waste and ash composts. *J Agric Sci* 5: 270–277.
25. Susilawati K, Ahmed OH, Majid NMA, et al. (2009) Effect of organic based n fertilizer on dry matter (*Zea mays* L.), ammonium and nitrate recovery in an acid soil of Sarawak, Malaysia. *Am J Appl Sci* 6: 1289–1294.
26. Lija M, Ahmed OH, Susilawati K (2014) Maize (*Zea mays* L.) nutrient use efficiency as affected by formulated fertilizer with Clinoptilolite Zeolite. Emirates. *J Food Agric* 26: 284–292.
27. Ch'ng HY, Yue YY, Suhaimi O, et al. (2018) Determination of extraction period and extractant ratio for extracting humic acid from rice straw compost. *Curr Agric Res J* 6: 150–156.
28. Havlin JL, Beaton JD, Tisdale, et al. (2005) Soil fertility and fertilizers: An introduction to nutrient management, 7Eds., 1700–1708, Upper Saddle River, NJ: Pearson Prentice Hall.
29. Bom FVD, Nunes I, Raymond NS (2018) Long-term fertilization form, level and duration affect the diversity, structure and functioning of soil microbial communities in the field. *Soil Biol Biochem* 122: 91–103.
30. Sanusi S, Ch'ng HY, Othman S (2018) Effects of incubation period and Christmas Island rock phosphate with different rate of rice straw compost on phosphorus availability in acid soil. *AIMS Agric Food* 3: 384–396.
31. Hamad MH, Desoky MA, Faragallah AA, et al. (2011) Effect of organic amendments on soil chemical properties and potassium availability to sorghum plants grown on a calcareous sandy soil. *Assiut J Agric Sci* 42: 65–76.
32. Ch'ng HY, Ahmed OH, Nik Muhammed NMA (2014) Biochar and compost influence the phosphorus availability, nutrients uptake, and growth of maize (*Zea mays* L.) in tropical acid soil. *Pak J Agric Sci* 51: 797–806.
33. Latifah O, Ahmed OH, Majid NMA (2015) Improving ammonium and nitrate release from urea using clinoptilolite zeolite and compost produced from agricultural wastes. *Sci World J*: 1–12.
34. Yazdanpanah N, Pazira E, Neshat A, et al. (2013) Reclamation of calcareous saline sodic soil with different amendments (II): Impact on nitrogen, phosphorous and potassium redistribution and on microbial respiration. *Agric Water Manag* 120: 39–45.

35. Liao P, Huang S, van Gestel NC, et al. (2018) Liming and straw retention interact to increase nitrogen uptake and grain yield in a double rice-cropping system. *Field Crops Res* 216: 217–224.
36. Fleming M, Tai Y, Zhuang P, et al. (2013) Extractability and bioavailability of Pb and As in historically contaminated orchard soil: Effects of compost amendments. *Environ Pollut* 177: 90–97.
37. Laekemariam F, Gidago G (2013) Growth and yield response of maize (*Zea mays* L.) to variable rates of compost and inorganic fertilizer integration in Wolaita, Southern Ethiopia. *Am J Plant Nutr Fert Technol* 3: 43–52.
38. Osman KT (2013) Problem soils and their management. In: Osman KT, Eds., Soils: Principles, Properties, and Management, Netherlands: Springer, 161–173.
39. Liu L, Guo X, Zhang C, et al. (2018) Adsorption behaviours and mechanisms of heavy metal ions' impact on municipal waste composts with different degree of maturity. *Environ Technol* 40: 1–15.
40. Zhang A, Liu Y, Pan G, et al. (2017) Effects of biochar amendment on maize yield and greenhouse gas emissions from a soil organic carbon, pool calcareous loamy soil from Central China plain. *Plant Soil* 351: 263–275.
41. Pan F, Yu W, Ma Q, et al. (2018) Do organic amendments improve the synchronism between soil N supply and wheat demand? *Appl Soil Ecol* 125: 184–191.