Dhaka Univ. J. Biol. Sci. **30**(2): 207-219, 2021 (July) DOI: https://doi.org/10.3329/dujbs.v30i2.54647

AMELIORATION OF SOIL ACIDITY BY THE APPLICATION OF MAIZE STRAW ASH IN MIXED SOIL

MD BAYAZID HOSSAIN*, MD HARUNOR RASHID KHAN, SAYMA KHANOM AND SHAHID AKHTAR HOSSAIN

Department of Soil, Water and Environment, University of Dhaka, Dhaka-1000, Bangladesh

Key words: Soil acidity, Maize straw ash, Mixed soil, Malabar spinach, Soil quality, Eco-friendly

Abstract

A pot experiment was conducted in the net house to evaluate the growth and yield response of two vegetables as influenced by the application of maize straw ash in mixed soil. The vegetables were White Malabar Spinach (*Basella alba* L.) and Red Malabar Spinach (*Basella rubra* L.). The mixing of acid soil with calcareous soil was done at 3:1 ratio. Maize straw ash was applied at different rates such as T_2 (1 ton/ha), T_3 (2 ton/ha) and T_4 (3 ton/ha). The control as T_1 received no amendment. Plant height, base diameter and fresh weight of the Spinach were significantly ($p \leq 0.05$) increased from the control treatment. All the studied growth parameters attained significant improvement for the T_3 (2 ton/ha) among all treatments in both the varieties of Malabar. Nutrient contents (N, P, K, S, Ca, Mg, Fe, Mn, Zn and Cu) of Red Malabar Spinach increased significantly for ash treatments and the highest increment of the N, P, S, Na, Ca, Mg and Zn were obtained by the T_3 treatment. For White Malabar Spinach, all the nutrients were increased significantly for T_3 compared to the control, except for the N (insignificant increase) and Ca (decrease). The application of maize straw ash at the rate of 2 ton/ha (T_3) increased plant growth, yield and nutrient contents in both the varieties of Malabar which might be attributed that, the maize straw ash can be considered as an amendment for the improvement of crop growth that may also have lasting effect on soil quality as well as economic and eco-friendly.

Introduction

Attaining global food security and environmental protection through the sustainable use of resources is a big challenge to all of us. Biomass is a substantial renewable resource that can be used as a fuel to produce different forms of energy[1]. It is classified as a form of green energy because it is both carbon-neutral and renewable. Today, biomass contributes about 9.5% of total primary energy supply and some 70% of renewable energy in use[2]. In some countries like Bangladesh, its use is about 90% for cooking and heating. Increasing biomass consumption for bioenergy is resulting the production of

*Author for correspondence: <bayazid@du.ac.bd>.

vast quantity of ashes. But land filling is still a common practice which is costly and wasting of valuable nutrients.

Besides being a renewable energy source, ashes from biomass incineration are also worth considering as reservoir of some essential nutrients. It could be returned to depleted soils as a supplement to organic fertilizers by suitable management practices. The beneficial effects of biomass ash from plant materials have been reported by many workers. It serves as a source of Ca, Mg, K, Na and to a lesser extent P, S, Zn, Si, etc.[3]. When added to acid soil, it increases the potential cation exchange, base saturation and pH; therefore counteracting the Al in soil indirectly[4]. Hence, the use of ash is considered as a credible alternative liming material and can be available at low cost to most semi-subsistence farmers[5]. Moreover, biomass ash can help to prevent the uptake of radio-nuclides and heavy metals by plants and decrease pollution risk to soils and groundwater[6]. On the other hand, ash adds a significant amount of organic matter to soil and improve water holding capacity. That’s why application of ash can improve the limitations of calcareous soil in a cheaper way also. Numerous studies have focused on the characterization and agricultural use of ash from wood combustion[7]. In contrast, ash generated from biomass has received less attention. However, information is very scanty concerning the characteristics of ashes from maize straw and its impact on nutrient status of soil and plant.

Cultivation of maize is getting popularity among Bangladeshi farmers day by day. A large portion of the maize straws are just cut down and thrown in nearby canals and water bodies to be rotten after harvesting. This practice clogs the normal water flow and deteriorates the water quality which eventually degrades the aquatic biodiversity of these water bodies. Besides, villagers use maize straw residues as fuel but hardly apply the ashes back to the field. This also hinders the cycling of nutrients.

Soil acidity and soil calcareousness are two of the major constraints in the land based agricultural production system throughout the world that is threatening global food security. Approximately 30% of the world's total land area consists of acid soils and it has been estimated that over 50% of the world's potential arable lands are acidic[8]. Acid soil occurs mainly in humid temperate forests and humid tropics and subtropics. On the other hand, calcareous soils are common in arid and semi-arid climates and occur as inclusions in more humid regions, affecting over 1.5 billion acres of soil worldwide[9]. These problems are also prominent to the farmer in different parts of Bangladesh. In Bangladesh, huge amount of lands is prevailed by soil acidity in the northwest, north central and northeast regions which is about 27% of land cultivated by 3.5 million farmers[10]. However, conventional liming materials are quite costly and sometimes detrimental to environment. On the other hand, calcareous soil is found in the western and south-western region of Bangladesh, total covering an area of 27,000 sq. km[11], which can be considered as an alternative to limes or liming materials to the above mentioned acid soils.

Against this background, the present study was undertaken as part of a group study with a view fighting against soil acidity and calcareousness through sustainable and ecofriendly ways. In this study, acid and calcareous soils were mixed in a ratio of 3:1 and ash from maize straw combustion was applied in the mixed soil as treatment. The objective was to find out the growth, yield and nutritional difference of vegetables grown in mixed soils which received maize straw ash as amendment.

Materials and Methods

Soil sampling and preparation: The pot experiment was conducted at the net house of the Department of Soil, Water and Environment, University of Dhaka. Two types of surface soils were collected (0-15 cm depth) by using spade from two different sites. Acid soil was collected from Binnapara, a village of Chehelgazi union of Dinajpur Sadar upazilla in Dinajpur district. The geographic location of Binnapara is $25^0 42^/ 52.58^{//}$N and $88^0 39^/ 36.07^{//}$E. On the other hand, calcareous soil was collected from Poschim Gangabardi, a village of Krishnonagar union of Faridpur Sadar upazilla in Faridpur district. The spatial location of the sampling site is $23^0 34^/ 59^{//}$N and $89^0 47^/ 17.9^{//}$E. After being air dried, soils were gently crushed by a wooden hammer. Then, ground samples were screened to pass through a 2 mm stainless steel sieve. After that the acid and calcareous soil samples were mixed properly in 3 : 1 ratio. The mixed soil got a status of pH of 7.03, EC of 362 μS/cm, 1.71% OM, 131 mg/kg available N, 10.1 mg/kg available P, 71 mg/kg available K, 22.8 mg/kg available S, 1530 mg/kg available Ca, 179 mg/kg available Mg, 60.3 mg/kg available Fe, 27.7 mg/kg available Mn, 2.1 mg/kg available Zn and 0.84 mg/kg available Cu.

Maize straw collection and analysis: Maize straws were collected from a field after the harvest and were burned in local cooking stoves. The ash was collected, smashed and sieved through 2 mm sieving and its chemical composition was determined (Table 1).

Pot preparation: Each earthen pot containing 2 kg friable soils mixed in a ratio of acid to calcareous soil was 3:1. A basal dose of N, P, K and S were applied as recommended by the Fertilizer Recommendation Guide(11). The pot experiment was conducted with two varieties of Malabar Spinach such as White Malabar Spinach (*Basella alba* L.) and Red Malabar Spinach (*Basella rubra* L.). Three different rates of maize straw ash such as 1 ton/ha, 2 ton/ha and 3 ton ha^{-1} were designated as T_2, T_3 and T_4 respectively were applied as amendment in the mixed soil. There was a control of mixed soil which was designated by T_1. Pots were kept according to Completely Randomized Design (CRD) with three replications. Certified seeds of two varieties of Malabar were sown into pots. After 50 days of sowing, the plants were harvested.

Analysis of the soil sample: The pH of soils was measured electrochemically by using combined electrode digital pH meter. The ratio of soil to water was 1: 2.5 by volume. The electrical conductivity of soils was measured at a ratio of 1:5 by a EC meter. The organic carbon of the soil sample was determined volumetrically by wet oxidation method of Walkey and Black. The organic matter was calculated by multiplying the percentage of organic carbon with conventional Van-Bemmelen's factor of 1.724. Available nitrogen was determined by extracting with 1*N* KCl and distilling with the help of Micro-Kjeldhal's distillation apparatus and the distillate was titrated against standard H_2SO_4. The available soil P of soils was estimated colorimetrically following the ascorbic acid blue color method and the extractant was analyzed by a Shimadzu UV-VIS spectrophotometer at 420 nm. Available K of soil was extracted by 1*N* ammonium acetate at pH 7.0 and was determined by a flame photometer (Jenway PFP7) at 767 nm wavelength. Available S content was determined in tween-80 method. It was measured by a spectrophotometer (Shimadzu UV-1800) at a wavelength of 420 nm. Soil available Ca and Mg was extracted by 1*N* ammonium acetate at pH 7.0 and were determined by Atomic Absorption Spectrophotometer. Available contents of micro-nutrients such as Fe, Mn, Cu and Zn; were determined by Atomic Absorption Spectrophotometer (Varian AA 240), after being extracted with DTPA solution at 1:2 ratio.

Table 1. Chemical composition of maize straw ash.

Properties	Values
pH	10.24
EC (µS/cm)	22.54
OC (%)	3.01
OM (%)	5.19
C.E.C (me/100 g)	151.93
Available N (mg/kg)	53.00
Total N (%)	0.22
Available P (mg/kg)	540.00
Total P (%)	1.27
Available K (%)	7.30
Total K (%)	13.01
Available S (mg/kg)	332.0
Total S (%)	0.85
Available Na (mg/kg)	125.3
Available Ca (%)	1.31
Available Mg (%)	0.68
Available Fe (mg/kg)	7.41
Available Mn (mg/kg)	21.0
Available Cu (mg/kg)	0.83
Available Zn (mg/kg)	5.95

Analysis of plant sample: After harvesting, fresh weight, height and diameter of the plants were measured. The leafy upper and root part were separated with a knife and processed individually. The samples were initially dried in the air and then oven dried at 70-80^{0}C for 3 days. Finally, the dried weight of the plant sample was taken. The dried plant samples were then ground in a grinder machine and were kept in a plastic container with proper label and stored in dry place for chemical analyses. The sample was digested by nitric acid and later perchloric acid. The digest was used for the determination of nutrient contents of plant. Plant N was determined by Micro-Kjeldhal's method following H_2SO_4 acid digestion and steam distillation with 40% NaOH. Evolved ammonia was collected in boric acid and then determined titrimetrically with standard 0.01 *N* H_2SO_4. After wet oxidation with HNO_3 and $HClO_4$ acids, plant contents of P, K, S, Na, Ca, Mg, Fe, Mn, Zn and Cu were determined by using the procedure mentioned earlier for soil.

Data analysis: A one-way analysis of variance (ANOVA) was used to analysis the significant difference between treatments. LSD test was also performed to assess the difference between parameters measured. Statistical analysis were conducted at > 95% confidence level ($p < 0.05$) using Microsoft Excel (2010) and SPSS (version 20).

Results and Discussion

Plant height: The height of White Malabar Spinach was observed to be increased significantly ($p \leq 0.05$) from control for the treatment T_3 (2 ton/ha) only. The highest (30.3 cm) and the lowest (26.4 cm) height was observed in T_3 (2 ton/ha) and T_1 (control) respectively (Fig. 1). Similar trend was observed for Red Malabar Spinach. The height of Red Malabar Spinach increased significantly ($p \leq 0.05$) comparing to control for all treatments. The highest (31.1 cm) was achieved by T_3 (2 ton/ha), followed by T_4 (3 ton/ha), T_2 (1 ton/ha) and the lowest (25.5 cm) was obtained in control (Fig. 1). In both cases, the highest height might be due to balanced effect of the amendment. The lowest was in control (T_1) soil; which might be due to lack of favorable nutritional condition.

The result of the experiment falls in line with the findings of Etiégni *et al.* (1991). They showed that the growth of wheat was increased about 25-69% by treating with crop residue ash.[12]. In another experiment, Melese and Yli-Halla investigated the effects of lime, wood ash, manure and mineral P fertilizer on plant growth in a pot experiment and found that the plant height, dry shoot biomass and P uptake increased significantly[13]. However, Leytem and Mikkelsen reported that plant growth was reduced in calcareous soil. They concluded that high pH resulted in unavailability of phosphate, reduction of micronutrient availability, e.g. boron, manganese, zinc and iron which limited the plant growth in these soils[9]. Biomass ash has been shown to reduce ground vegetation cover at dosages of >5 ton/ha[14]. All these results may validate the increase of plant height with increasing dose of maize straw ash to a certain extent.

Base diameter: The base diameter of White Malabar Spinach increased significantly ($p \leq 0.05$) from control for all treatments while the base diameter of Red Malabar Spinach increased significantly ($p \leq 0.05$) over control for treatment T_3 (2 ton/ha) only. The highest (27.0 mm) and the lowest (22.4 mm) diameter of White Malabar Spinach was observed in T_3 (2 ton/ha) and T_1 (control) respectively (Fig. 2). On the other hand, for the highest (28.8 mm) was found in T_3 (2 ton/ha), followed by T_2 (1 ton/ha), T_4 (3 ton/ha) and the lowest (26.7 mm) was obtained in control (T_1).

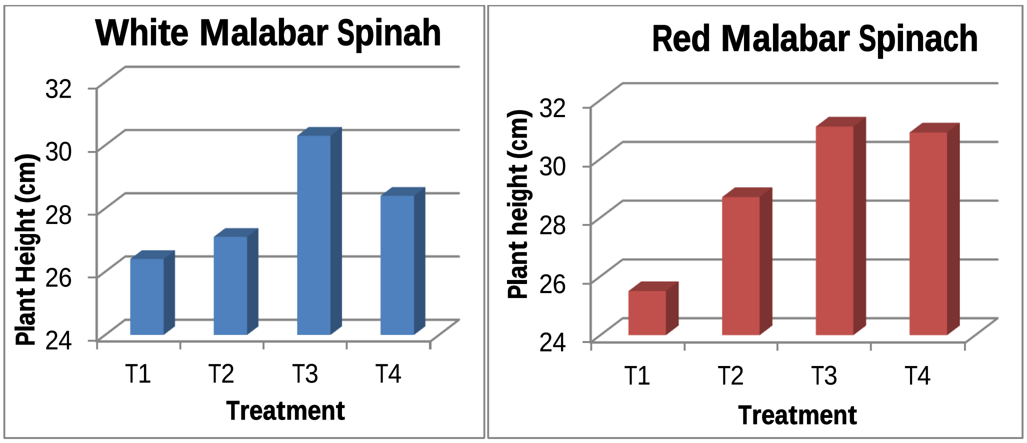

Fig. 1. Response of maize straw ash treatments on plant height.

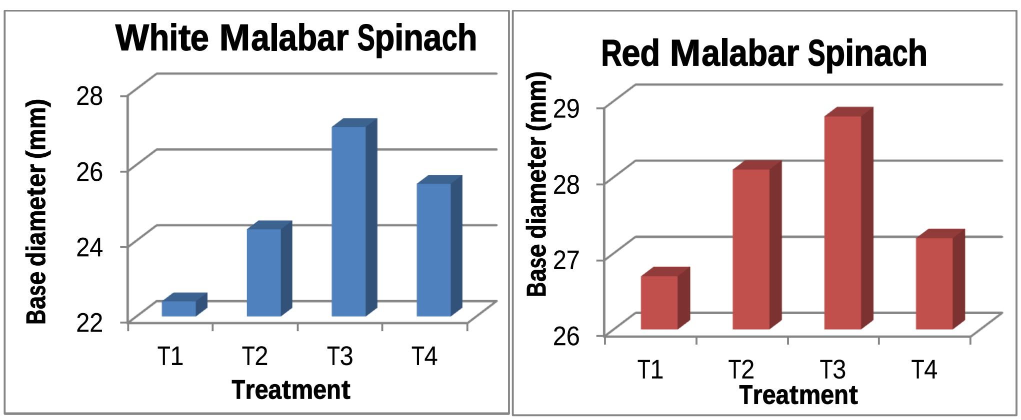

Fig. 2. Response of maize straw ash treatment on base diameter.

Fresh weight: The fresh weight of White Malabar Spinach was increased significantly ($p \leq 0.05$) comparing to control for all treatments except T_2 (1 ton/ha) but for Red Malabar Spinach, it increased significantly ($p \leq 0.05$) from control for all treatments. The highest (80.6 ton/ha) and the lowest (71.6 ton/ha) fresh weight of White Malabar Spinach was observed in T_3 (2 ton/ha) and T_1 (control) respectively (Fig. 3). On the contrary, for Red

Malabar Spinach, the highest fresh weight (82.5 ton/ha) was achieved by T_3 (2 ton/ha), followed by T_4 (3 ton/ha) and the lowest (72.5 ton/ha) was obtained in control (Fig. 3).

This experiment showed that application of maize straw ash as an amendment has positive impacts on yield production of two cultivars of Malabar which was also found by Shi *et al.*. They found that the application of biomass ash was beneficial to the growth and yield of wheat(4). Melese and Yli-Halla (2016) investigated that increasing rates of wood ash application significantly increased fresh shoot biomass(13). Krejsl and Scanlon (1996) observed the significant increase of biomass production of Oats and Beans that were grown in soils treated with ash(15). Soil calcareousness causes deficiency of N, P, K, Mg, Z, Cu and Fe which lead to low yield(16).

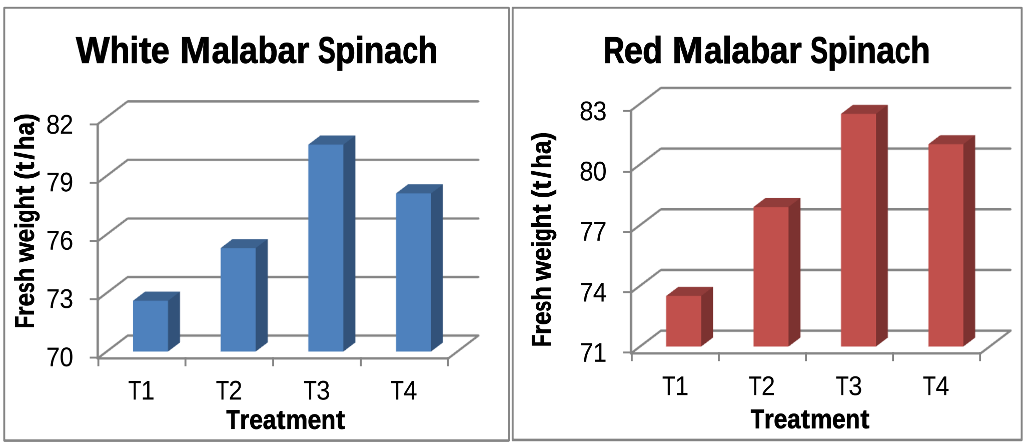

Fig. 3. Response of maize straw ash treatment on fresh weight

Macronutrient Concentration

White Malabar Spinach: The highest (0.33%) nitrogen content in White Malabar Spinach was observed for T_3 (2 ton/ha) and the lowest (0.27%) for T_2 (1ton/ha), respectively (Fig. 4a). However, this increment with maize straw ash was not statistically significant. Phosphorus content was increased significantly ($p \leq 0.05$) from control for all treatments and the highest (0.74 %) was found for T_3 (2 ton/ha) and the lowest (0.59 %) for the control (Fig. 4b). The highest (9.39 %) potassium content was observed for T_4 (3 ton/ha) and the lowest (6.9 %) for T_1 (control), respectively (Fig. 4c) and all treatments increased K content significantly ($p \leq 0.05$) over control except T_2 (1 ton/ha). The highest (0.8%) sulphur in White Malabar Spinach was observed for T_3 (2 ton/ha) and the lowest (0.58%) for T_4 (3 ton/ha) respectively (Fig. 4d). However, significant ($p \leq 0.05$) increase of sulphur content comparing to control was seen for T_3 (2 ton/ha) only. The highest (0.61%) calcium content was observed for T_4 (3 ton/ha) and the lowest (0.28%) for T_2 (1 ton/ha) respectively (Fig. 4e). This nutrient content was decreased significantly ($p \leq 0.05$) for T_2 (1 ton/ha) and T_3 (2 ton/ha) from control but was increased insignificantly ($p \leq 0.05$) in T_4 (3 ton/ha). Magnesium content in White Malabar Spinach was increased significantly ($p \leq 0.05$) from control for all treatments. T_4 (3 ton/ha) produced the highest (0.91%) while the lowest (0.62%) was seen for T_1 (control) respectively (Fig. 4f).

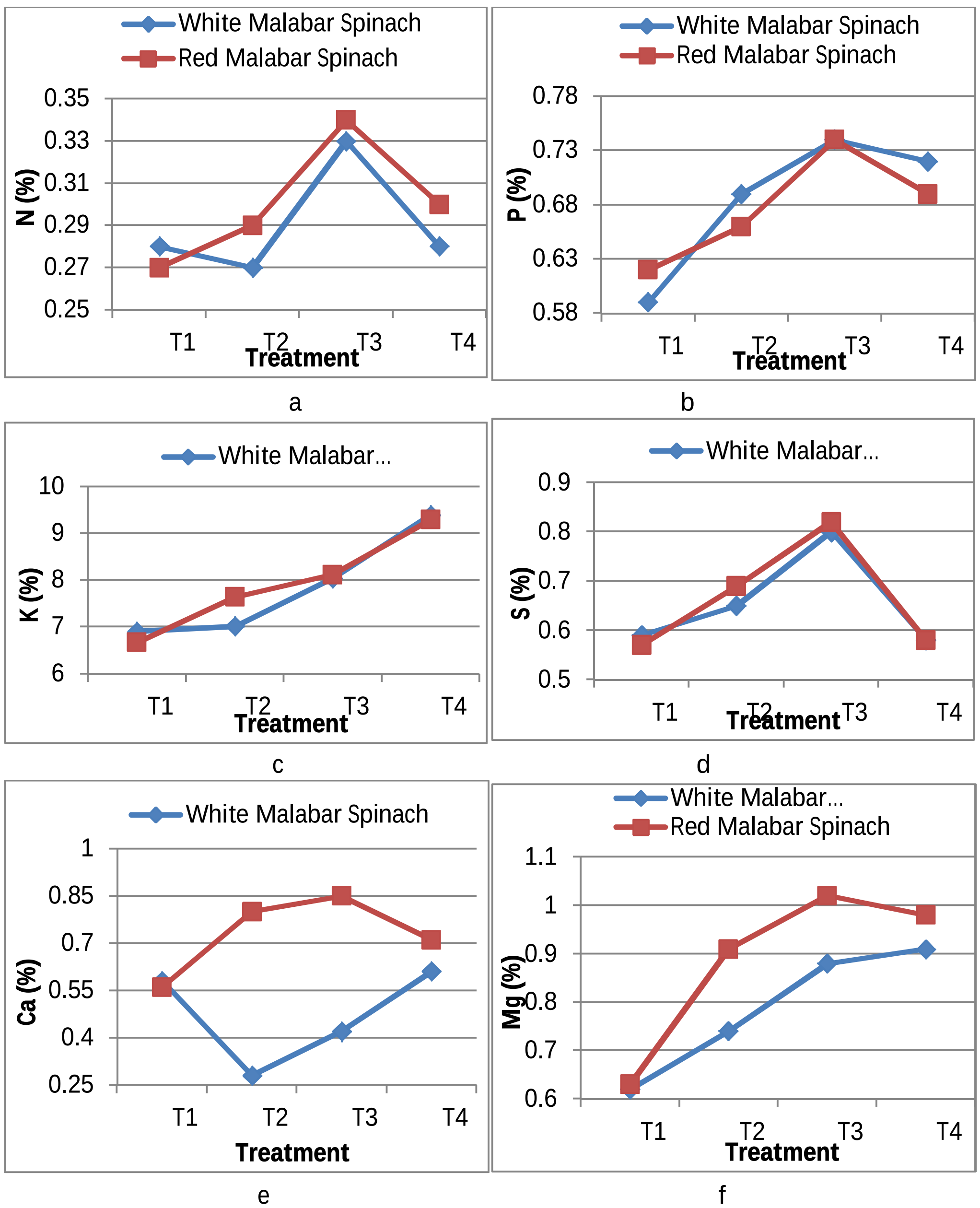

Fig. 4. Response of maize straw ash on macronutrient contents.

Red Malabar Spinach: The nitrogen content in Red Malabar Spinach was increased significantly ($p \leq 0.05$) only for T_3 (2 ton/ha) from the control and the highest (0.34%) was observed for T_3 (2 ton/ha) and the lowest (0.27%) for T_1 (control) respectively (Fig. 4a). Similar trend was found for phosphorus content (0.74% and 0.62%) respectively (Fig. 4b). However, all treatments caused significant increase ($P \leq 0.05$) of P content from control except T_2 (1 ton/ha). The potassium content was increased significantly ($p \leq 0.05$) comparing to the control for all treatments and the highest (9.29%) was observed for T_4 (3 ton ha^{-1}) and the lowest (6.67%) for T_1 (control) respectively (Fig. 4-c). The highest (0.82%) sulphur content was observed for T_3 (2 ton/ha) and the lowest (0.57%) for T_1 (control) respectively (Fig. 4-d). However, sulphur content of Red Malabar Spinach was increased significantly ($p \leq 0.05$) from control for all treatments except T_4 (3 ton/ha). The calcium content of was increased significantly from control for all treatments and T_3 (2 ton/ha) caused the highest (0.85%) while the lowest (0.56%) was observed for T_1 (control) respectively (Fig. 4e). Similar outcome was observed in magnesium (1.02% for T_3 and 0.63% for T_1), respectively (Fig. 4f).

Several scientists attributed to the fact that biomass ash is a source of soluble P in addition to its liming effect[4,5]. The increase in P uptake by plant for ash may be attributed to the increases in soil pH, reduction in the toxicity of Al^{3+} and Mn^{2+} and reduction in nutrient deficiency[17]. Higher rates of maize straw ash may have increased soil pH to the range in which P is less available and could explain decreases in foliar P[18]. Foliar K concentrations were generally increased compared to the controls in all ash treatments. K is the most soluble nutrient in biomass ash[19], and increased foliar K as expected and are consistent with previous studies using other species[20,21].

Previous studies reported the increases in foliar Ca concentrations by biomass ash application[22]. Application of ash increases in foliar concentrations of Ca is, irrespective of soil type[23]. Ash is a particularly rich source of Ca. But from this experiment it can be observed that the calcium content in White Malabar Spinach decreased for two treatment such as T_2 (1 ton/ha) and T_3 (2 ton/ha) than control. Similar trend was found by Gorgolewski. He observed that, at higher dosages, uptake of Ca was decreased and he thought that this might be due to either the antagonistic effects of Na or excessive increases in soil pH[18]. Mandre *et al.* (2010) reported decreases in foliar Ca levels in seedlings treated with ash and suggested this was due to competition with the abundant K supply[21]. However, the reason of decreasing of Ca content in White Malabar Spinach only could not be known. The effects of maize straw ash on magnesium uptake by plants were a result of its influence on soil pH, nutrient content and nutrient availability. Biomass ash is a source of Mg normally. These findings are consistent with previous work[22].

Micronutrient Concentration

White Malabar Spinach: The iron content of White Malabar Spinach was increased significantly ($p \leq 0.05$) from control for all treatments. The highest (0.48%) iron content was observed for T_3 (2 ton/ha) and the lowest (0.19%) for T_1 (control) respectively (Fig. 5a). Similar trend was observed for manganese content. The highest (257 mg/kg) manganese content was observed for T_4 (3 ton/ha) and the lowest (65 mg/kg) for T_1 (control), respectively (Fig. 5b). The highest (101.9 mg/kg) zinc content in White Malabar Spinach was observed for T_3 (2 ton/ha) and the lowest (31.1 mg/kg) for T_2 (1 ton/ha), respectively (Fig. 5c). However, it was increased significantly ($P \leq 0.05$) for T_3 (2 ton/ha) and T_4 (3 ton/ha) from control but decreased significantly for T_2 (1 ton/ha). All treatments increased the copper content significantly ($p \leq 0.05$) over control. The highest (17.5 mg/kg) copper content was observed for T_3 (2 ton/ha) and the lowest (8.4 mg/kg) for T_1 (control), respectively (Fig. 5d).

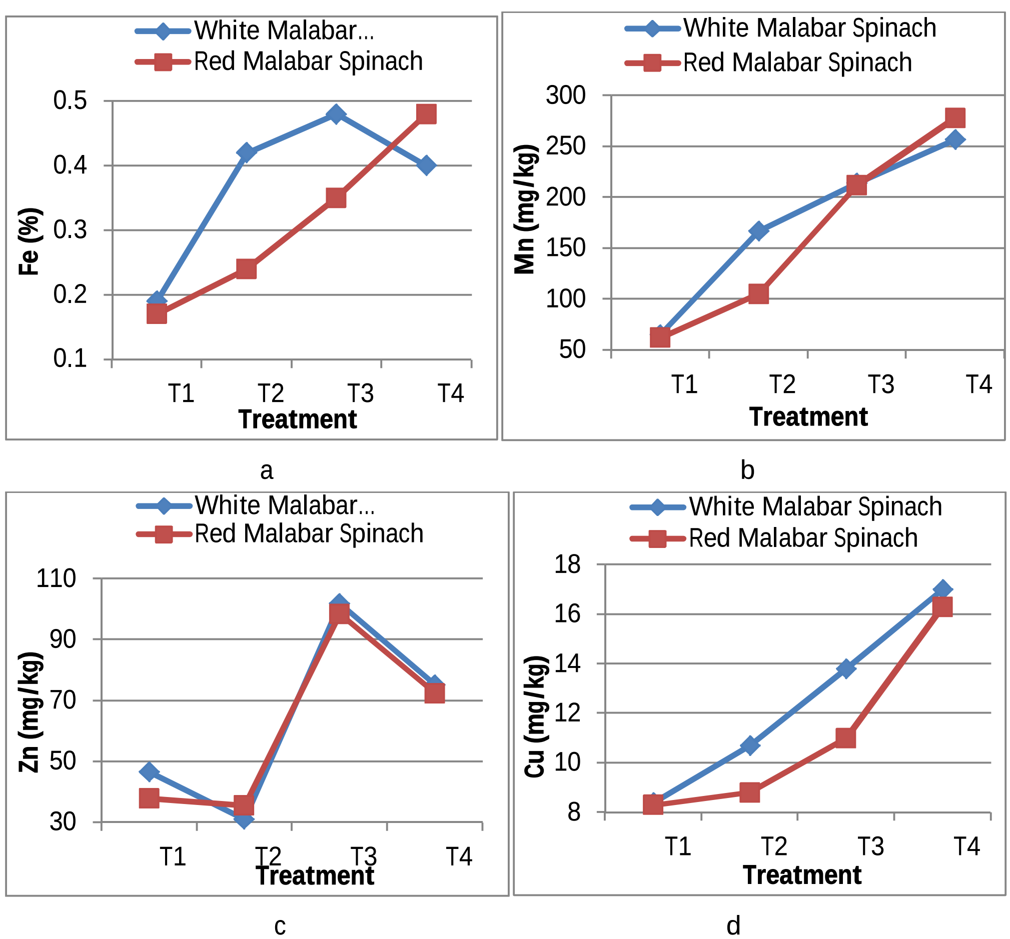

Fig. 5. Response of maize straw ash on micronutrient contents.

Red Malabar Spinach: Application of maize straw ash increased the iron content in Red Malabar Spinach significantly ($p \leq 0.05$) from the control for all treatments. The highest (0.48%) iron content was observed for T_4 (3 ton/ha) and the lowest (0.17%) in T_1 (control), respectively (Fig. 5a). Identical result was found for manganese content and the highest and the lowest was 278 mg/kg and 62 mg/kg, respectively (Fig. 5b). The highest (98.4 mg/kg) zinc content was observed for T_3 (2 ton/ha) and the lowest (35.5 mg/kg) for T_2 (1 ton ha^{-1}) respectively (Fig. 5c). However, all treatments increased the zinc content in Red Malabar Spinach significantly ($p \leq 0.05$) from control except T_2 (1 ton/ha). The highest (16.3 mg/kg) copper content was observed for T_4 (3 ton/ha) and the lowest (8.2 mg/kg) for T_1 (control) respectively (Fig. 5d) and it was increased significantly ($p \leq 0.05$) from control for all treatments except T_2 (1 ton/ha).

Increasing rate of maize straw ash application tended to increase the foliar Fe content. This might be because maize straw ash acted as a source of Fe. Mn is most available in soil with lower pH values. However, increasing rate of maize straw ash application increased the foliar Mn content which is not consistent with previous work[(18)]. This might be because maize straw ash acted as a source of Mn. Increases in foliar Cu and Zn for biomass ash treatment have been reported by Osteras *et al* (2005).[(24)]. Available zinc content of the soil changed into double after the wood ash treatment[(25)]. The findings of this study concede with them.

In conclusion, the findings of the experiment showed that the growth parameters, most of the macro and micronutrient concentration of two varieties of Malabar Spinach were significantly ($P \leq 0.05$) increased from control. Among all treatments, T_3 (2 ton ha^{-1}) showed the best improvement. From the study, it can be observed that application of maize straw ash in the mixed soil can be considered as a viable option to achieve sustainability and security in food production.

References

1. Quirantes M, E Romero and R Nogales 2016. Nutrient availability in a calcareous soil amended with different types of biomass ash. Comm. Soil Sci. Plant Analysis **47**(20): 2271-2280.
2. IEA (International Energy Agency) 2019. Key world energy statistics 2019. pp. 81.
3. Chindi K 2014. Evaluation of chemical reactivity of local liming materials to improve the quality of acidic soils in Zambia. Department of Physical Land Resources, Ghent University, Belgium. pp. 70.
4. Shi RY, JY Li, N Ni, K Mehmood, RK Xu and W Qian 2017. Effects of biomass ash, bone meal, and alkaline slag applied alone and combined on soil acidity and wheat growth. J. Soils Sediments **17**: 2116-2126.
5. Insam, H, IH Whittle, BA Knapp and R Plank 2009. Use of wood ash and anaerobic sludge for grassland fertilization: Effects on plants and microbes.Bodenkultur **60**: 43-55.
6. Goulding, KWT and L Blake 1998. Land use, liming and the mobilization of potentially toxic metals. Agri. Ecosystem Environ. **67**: 135-144.

7. Bougnom BP, C Niederkofler, BA Knapp, E Stimpfl, H Insam 2012. Residues from renewable energy production: Their value for fertilizing pastures. Biomass Bioenergy **39**: 290–295.

8. von Uexküll HR and E Mutert 1995. Global extent, development and economic impact of acid soils. Plant Soil **171**: 1-15.

9. Leylem AB and RL Mikkelsen 2005. The nature of phosphorous in calcareous soils. Better Crops **89**(2): 11-13.

10. Solaiman ASM 2014. Land degradation in Bangladesh: A challenge to face food security. Department of Agroforestry and Environment, BSMRAU, Gazipur.

11. FRG (Fertilizer Recommendation Guide) 2012. Bangladesh Agricultural Research Council, Government of Bangladesh. pp. 274.

12. Etiégni L, A Campbell and R Mahler 1991. Evaluation of wood ash disposal on agricultural land. Potential as a soil additive and liming agent. Comm. Soil Sci. Plant Analysis **22**(3-4): 243-256.

13. Melese A and M Yli-Halla 2016. Effects of applications of lime, wood ash, manure and mineral P fertilizer on the inorganic P fractions and other selected soil chemical properties on acid soil of Farta District, Northwestern of Ethiopia. African J. Agri. Res. **11**(2): 87-99.

14. Pitman R 2006. Wood ash use in forestry - A review of the environmental impacts. Forestry **79**: 563-588.

15. Krejsl J and T Scanlon 1996. Evaluation of beneficial use of wood-fired boiler ash on oat and bean growth. J. Environ. Quality **25**: 950-954.

16. Hassan, 2012. Soil Science. Institute of African Research and Studies, Cairo University, Egypt. pp. 20.

17. Oluwatoyinbo FI, MO Akande and JA Adediran 2005. Effects of rock phosphate amended with poultry manure on soil available p and yield of maize and cowpea. African J. Biotechnol. **4**(5): 444-448.

18. Gorgolewski A 2015. Wood ash as a forest soil amendment: effects on seedling growth and nutrition, and red-backed salamander abundance. Faculty of Forestry, University of Toronto. pp. 74.

19. Augusto L, M Bakker and C Meredieu 2008. Wood ash applications to temperate forest ecosystems-potential benefits and drawbacks. Plant Soil **306**: 181-198.

20. Kloseiko J, T Kuznetsova, M Tilk and M Mandre 2014. Short-term influence of clinker dust and wood ash on macronutrients and growth in Norway spruce (*Picea abies*) and scots pine (*Pinus sylvestris*) seedlings. Comm. Soil Sci. Plant Analysis **45**: 2105-2117.

21. Mandre M, H Parn, J Kloseiko, M Ingerslev, I Stupak, M Kort and K Paasrand 2010. Use of biofuel ashes for fertilisation of *Betula pendula* seedlings on nutrient poor soil. Biomass Bioenergy **34**: 1384-1392.

22. Solla-Gullon F, M Santalla, C Perez-Cruzado, A Merino and R Rodriquez-Soalleiro 2008. Response of *Pinus radiate* seedlings to application of mixed wood-bark ash at planting in a temperate region: Nutrition and growth. Forest Ecol. Manage. **255**: 3873-3884.

23. Reid C. and S Watmough 2014. Evaluating the effects of liming and wood-ash treatment on forest ecosystems through systematic meta-analysis. Canadian J. Forest Res. **44**: 867-885.

24. Osteras AH, I Sunnerdahl and M Greger 2005. The impact of wood ash and green liquor dregs application on Ca, Cu, Zn and Cd contents in bark and wood of Norway spruce. Water Air and Soil Pollution **166**: 17-29.

25. Fuzesi I, B Heil and G Kovacs 2015. Effects of wood ash on the chemical properties of soil and crop vitality in small plot experiments. Acta Silv. Lign. Hung. **11**(1): 55-64.

(Manuscript received: 24 April, 2021; accepted: 30 May, 2021)