*Journal of Engineering and Technology*
*The Open University of Sri Lanka (JET-OUSL), Vol. 10, No.1, pp. [16-32], 2022*

# Tea factory firewood ash as a potential plant nutrient source for higher productivity of mature tea in Matara District of Sri Lanka

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***Abstract***: *Tea industry has waste products such as refuse tea from made tea production while ash from fire wood. There are 705 tea factories located island wide, nearly 35,250 kg of wood ash is being produced every day as approximately 50 kg of wood ash is being produced in a tea factory for a day. Lack of information on wood ash, composition as well as the plant nutrient value of wood ash, have led the application of wood ash to tea plantation is limited. Therefore, the main objective of this study is to investigate the suitability of tea factory wood ash as a plant nutrient source for mature tea. The experiment was conducted in the Field number 1B, Mervillian Division, Kiruwanaganga Estate at Deniyaya in Matara district. The different rates of wood ash (500, 1000 kg ha$^{-1}$ year$^{-1}$) and refuse tea (20t/ha/yr) or compost (20t/ha/yr) were compared with current fertilizer mixture, VPLC 880. Ten experimental plots were marked out for 5 treatments and controlled by current recommended mixture with 200 bushes per each plot as two replicates for each treatment. The soil pH values were measured with distilled water varied significantly among treatments. The higher pH values can be seen in the plots treated with wood ash compared with inorganic mixture applied plots. Soil available phosphorous content did not vary significantly with treatments. Soil available potassium varies significantly among treatments. The concentration of the soil potassium in wood ash applied pots with compost significantly differs with other treatments especially with inorganic mixture applied plots. Soil available Mg varied significantly among treatments. The concentrations of the soil Mg in wood ash applied pots at 1000kg/ha/yr with either compost or refuse tea significantly differ with other treatments especially with inorganic mixture applied plots. Soil available Ca varied significantly among treatments. The concentration of the soil Ca in wood ash applied pots at 1000kg/ha/yr. with either refuse tea or compost significantly differs with other treatments especially with inorganic mixture applied plots. No significant difference in organic carbon content was observed among treatments. The CEC of the soil in wood ash applied pots at refuse tea significantly differ with other treatments especially with inorganic mixture applied plots. Significant difference in N, P and K content in the mother leaves were observed among treatments. Highest value was observed in wood ash applied pots at refuse tea at 1000kg/ha/yr. Wood ash applied plots showed comparable yield with present TRI fertilizer recommendation. The highest made tea yield was obtained in wood ash applied at 1000kg/ha/yr with refuse tea plots. Therefore, wood ash with refuse tea could be used to produce highest yield of made tea.*

***Key words***: *Tea, nutrient, soil, wood ash, refuse tea*

# 1. INRODUCTION

Agriculture is a vital and dynamic component in the economy of Sri Lanka, due to its contribution to country's income, employment, welfare and culture (Gunasekare, 2012). Plantation crops such as Tea, Rubber and Coconut act major role in agriculture sector in Sri Lanka. Out of them tea is very important, because income from the agriculture sector contributes about 19.7% of the total Gross National Production (GNP) of which the contribution from tea is about 70% and tea contributed 1.3% to Gross Domestic Production (GDP) (Annual report of Tea Research Institute, 2011). Tea export earnings reached USD 1.5 Billion in 2011, a historically high value contributing 15% to the nation's foreign exchange and generating 65% of export agriculture revenue and 2 Million employments directly and indirectly. Altogether 10% of the population of Sri Lanka depends on this industry (Samaraweera *et al.*, 2013).

Any industry always has waste products. In tea industry there are waste products such as refuse tea from made tea production and ash from fire wood. Refuse tea commonly used to protein extraction through membrane filtration technique for instant tea production and use as a mulching material and compost for tea plantations (Annual report of Tea Research Institute, 2003).

The manufacture of black tea from green leaf delivered to the factory requires the following stages of processing. They are withering, rolling, roll breaking, fermentation, drying, shifting, grading and packaging. Wood ash is being released through the drying stage which is an expensive component in processing of tea. A large quantity of hot air is required for this purpose. Common energy sources used in the tea industry are fuel and firewood.

Firewood is the low-cost energy source and it releases minimum undesirable sulfur containing gases respect to the fuel. Withering also required hot air from furnace where firewood is used. Wood ash is the second highest waste from tea manufacture, does not used in a beneficial way though rarely used to produce compost. Even though, our forefathers used ash as an input to the crops they do not know the value of ash.

As a result of the oxidation processes during combustion the generated wood ash retains the overall composition of the mineral nutrients contained in the firewood with the exception of nitrogen compounds, which are mainly released into the environment as gas. Nutrient elements contained in the form of fixed substances are relatively stable during the burning thermal treatment. These elements are in the same proportions as they were in the structure of the wood piece, which is a prerequisite for a good methods and technologies for use in the chemo dynamic cycle of the elements in the soil systems. Nitrogen compounds from the wood piece in the combustion process are degraded and released in the atmosphere as a waste gas mainly in the form of oxides (Sène and Gallet, 2001). Therefore, wood ash may be a good source of plant nutrient.

There are so many liming materials that can be incorporated to maintain the soil pH ranges which suitable for specific crop. Tea prefers acidic soil with pH 4.5-5.5. Present of comparatively high levels of Potassium (K), Calcium (Ca), and Magnesium Carbonate ($MgCO_3$) or Oxides in wood ash, which gives the strongly alkaline reaction, can neutralize acid soils. Therefore, it can be used as a low-cost liming material to crops. It is better to study nutrition composition of wood ash, neutralizing power of wood ash and what amount of ash going to be applied to crops as a nutrient source (Anandacoomaraswamy *et al*, 2003).

Although huge amount of wood ash is being removed from tea factories in Sri Lanka, there is still no efficient and proper way to reap the maximum benefit out of wood ash from tea factory. There are 705 tea factories located island wide so nearly 35,250 kg of wood ash is being produced every day as approximately 50 kg of wood ash is being produced in a tea factory for a day (Table 1). (Annual report of Tea Research Institute, 2011)

Lack of information on wood ash composition as well as the plant nutrient value of wood ash, have led the application of wood ash to tea plantation to be limited. Therefore, an in-depth study of wood ash would be able to provide invaluable information to interpret and recommend wood ash more rationally to the stakeholders.

**Table .**1: Number of tea factories located in Sri Lanka

| **Regions** | **Numbers of factories located** |
|---|---|
| Up-country | 130 |
| Low country | 416 |
| Mid-country | 093 |
| Uva regions | 066 |
| **Total** | **705** |

## 2. METHODOLOGY

### *2.1. Location*

The experiment was carried out at the Kiruwanaganga Estate at Deniyaya in Matara district

### *2.2. Soil*

According to the soil classification systems, this soil has been classified as Red Yellow Podzolic Great soil group and Weddagala soil series. It is a well-drained soil which having sandy clay loam texture and sub angular blocky soil structure. It is a kind of deep soil.

**Table 2**: Chemical properties of the soil

| **Property** | **Value/Concentration** |
|---|---|
| pH | 3.48 |
| Organic carbon | 1.02 |
| Nitrogen (%) | 0.27 |
| Phosphorus (mg/kg) | 11 |
| Potassium (mg/kg) | 98 |
| Magnesium (mg/kg) | 24 |
| Sulphur (mg/kg) | 47 |
| Calcium (mg/kg) | 78 |
| Manganese (mg/kg) | 2.55 |
| Copper(mg/kg) | 0.34 |
| Zinc (mg/kg) | 2.80 |
| Iron (mg/kg) | 4.60 |
| Boron (mg/kg) | 0.57 |

### 2.3. Experimental design and treatments

A randomized complete block design (RCBD) was used as the experimental design having 10 plots surrounded by guard raw which separated the treated area in order to prevent effects in any adjacent plots to influence the experiment. The five treatments were replicated twice. The treatments used are shown in the Table 3.

**Table 3:** Treatments details of wood ash trial

| Treatments | Details |
|---|---|
| T1 | Wood ash (WA) (500kg/ha/yr) + Compost (20t/ha/yr) |
| T2 | Wood ash (WA) (1000kg/ha/yr) + Compost (20t/ha/yr |
| T3 | Wood ash (WA) (500kg/ha/yr) + Refuse tea (20t/ha/yr) |
| T4 | Wood ash (WA) (1000kg/ha/yr) + Refuse tea (20t/ha/yr) |
| T5 | Current recommendation (VPLC 880) |

## 2.4. The composition of treatment materials

### *2.4.1. Wood ash*

There are so many tree species used as firewood in tea industry of Sri Lanka. Wood ashes were sieved by using 0.5 mm sieve and sieved pure rubber wood ash was used (Table 4).

**Table 4:** Nutrient composition of rubber wood ash

| Parameter | Value/Concentration |
|---|---|
| pH | 13.66 |
| EC | 5.58 |
| Organic Carbon (%) | 0.16 |
| Total Nitrogen (%) | 0.13 |
| Potassium (%) | 7.26 |
| Phosphorous (%) | 0.78 |
| Sulphur (%) | 1.13 |
| Magnesium (%) | 2.15 |
| Calcium (%) | 24.91 |
| Boron (mg/kg) | 1337 |
| Iron (mg/kg) | 723 |
| Zinc (mg/kg) | 255 |
| Copper(mg/kg) | 135 |
| Manganese | 1432 |

#### 2.4.2. VPLC 880 fertilizer mixture

Composition of VPLC 880 mixture is as follows:

| | | |
|---|---|---|
| Urea | parts | 587 |
| ERP | parts | 126 |
| MOP | parts | 167 |
| | | 880 |

The mixture contains approximately 30.7% N, 4.1% $P_2O_5$ and 11.4% $K_2O$

#### *2.4.3. Compost*

Compost is a very common nutrient supplement in Tea lands. The composition of compost is shown in Table 5.

**Table 5:** Nutrient composition in compost

| **Parameter** | **Concentration** |
|---|---|
| Total Carbon content (%) | 36.5 |
| Total Nitrogen (%) | 3.0 |
| C/N ratio | 12.3 |
| Phosphorous (%) | 0.4 |
| Potassium (%) | 4.4 |
| Calcium (%) | 1.01 |
| Magnesium (%) | 0.35 |
| Zinc (mg/kg) | 81 ppm |
| Manganese (mg/kg) | 551 ppm |

#### *2.4.4. Refuse Tea*

Tea industry has waste products such as refuse tea coming from made tea production in large quantities. Nutrient composition of refused teas is shown in table 6.

**Table 6**: Nutrient composition in refuse tea

| Compositions | Concentration |
|---|---|
| Total Nitrogen (%) | 3.44 |
| Phosphorous (%) | 0.34 |
| Potassium (%) | 2.10 |
| Calcium (%) | 0.34 |
| Magnesium (%) | 0.19 |
| Copper (mg/kg) | 28 |
| Manganese (mg/kg) | 146 |
| Zinc (mg/kg) | 34 |
| Iron (mg/kg) | 218 |

## 2.5 Sampling procedure

### *2.5.1. Ground fertilizer application*

VPLC 880 ground fertilizer mixture was applied to all plots as TRI recommended amount just after plot marking.

### *2.5.2. Soil samples*

Pre soil sampling was done 3 months after applying the VPLC 880 ground fertilizer mixture. The soil samples were taken from two depths of 0-15 cm and 15-30 cm. The samples were collected randomly and three samples from each plot in Z manner, from the plots after removing the surface litter. The collected samples were air dried and sieved by using 0.5mm and 2mm sieves for total and available nutrient analysis respectively.

### *2.5.3. Leaf samples*

Leaf sampling was done 3 months after ground fertilizer application. Two mother leaves were collected from each bush in the plot to provide a composite sample. The leaves were put into paper bags with the label, and placed in the electric oven and kept overnight at 80˚ C. The dried samples were crushed by hand and a sub sample ground in intermediate mill and passed through a 40-mesh stainless steel sieve. At the time of weighing the powdered sample was thoroughly mixed with a spatula.

*2.5.4. Yield recording*

Yield recording was started after plot marking and it will continue throughout the experimental period. Yield was recorded at 7-10 days interval. Harvested from each plot was weighed separately using a top loading balance. Only two pluckers were used for plucking each plot to minimize the plucking error.

## 2.6 Analytical procedures

*2.6.1. Soil Analysis*

- ***Determination of soil pH using distilled water***

Determination of pH of the soil suspension was done using a pH meter (ORION 550A model, USA) with the Ag/AgCl combined electrode. Prior to determination, the meter was calibrated using commercially available buffer solution of pH 4.0 and 7.0 BDH brand. A 10 g sample of soil was weighed into pH cup. Thereafter, 25ml of distilled water was added into each pH cup and stirred well and kept for 30 minutes. Then stirred again and pH reading was taken by using pH meter.

- ***Determination of Available Potassium, Magnesium, Calcium in soil***

Five grams of soil was weighed into plastic bottle and 25 ml of 1N Ammonium Chloride solution ($NH_4Cl$) solution was added. Then, it was shaken for 30 minutes. Shaken sample was filtered by 542 Whatman filter paper into a jam bottle. Then 3ml of aliquot were pipetted out into volumetric flask and 2.5ml SrCl2 solution was added to make the volume up to 25ml. Then readings were taken by Atomic Absorption Spectrometer for Magnesium, Calcium and by flame photometer for Potassium.

- ***Determination of D.T.P.A (Die ethylene Triamine Pentaacetate) extractable (Mn) Trace element in soil***

Air dried, sieved (pass through 2mm mesh) 10g of soil was weighed into the shaking bottles. Then 20ml of Di DTPA extracting solution was added into it and shacked for two hours, centrifuge and filter. Filtrate was collected into a jam bottle and Atomic absorption spectrophotometer was used to determine the concentration of each element by using the Holo- cathode lamp for each element.

- ***Determination of Total Nitrogen of soil (Kjeldahl method)***

One gram of finely ground air-dried soil was weighed into a 100 ml digestion tube which has 75 ml graduation mark on its neck and added sufficient water to just moisten the soil completely. Then 2 g of the catalyst was added and carefully and 4 ml con. $H_2SO_4$ was poured in such a way as to wash down all soil particles adhering to the neck of the tube. Then the contents of the flask were mixed well and started the digestion in a fume cupboard. The contents were boiled for 1 hour after the digest turns green. When cool down to the room temperature few drops of water was added and mixed well. After that the digesta was transferred quantitatively in to a 1-literKjeldahl flask. Then 25 ml of 40% NaOH was added in such a way that the alkali settles at the bottom of the flask. Then a 200 ml conical flask containing 25 ml 4% boric acid and 2 drops indicator was fitted to the delivery tube of the distillation unit. After that the apparatus was connected to the Kjeldahl bottom flask. The distillation was started and collected about 100ml of distillate. The receiving flask was removed, washed the delivery tube with distilled water and the contents were titrated with 0.10N HCl.

- ***Determination of Cation Exchange Capacity***

Soil samples were air dried and passed through 2mm sieve. From each sample12.5 g of soil was measured and put into the folded filter paper (Whatman 542) in a funnel. Next the funnel was fixed to a 250cm$^3$ volumetric flask, and the content was leached with 1N $NH_4Cl$ solution until around 250cm$^3$ was collected. After that the same content was leached with 1/20N NH4Cl solution until around 250cm$^3$ of the leachate was collected. During these two processes, most of the cations in the soil sample were replaced by $NH_4^+$ ions. Consequently, leaching the same soil with 1N Sodium Sulphate ($Na_2SO_4$) solution did the replacement of $NH_4^+$ ions. This was done until 250 cm$^3$ leachet was collected. Finally, 25.00cm$^3$ of the collected solution was steam distilled in the Kjeldahl distillation apparatus (BUCHI B 324 model, Netherlands) and the evolved ammonia was collected in the boric acid solution. Ultimately, the amount of ammonia was determined by titrating with standardized 0.1 $NH_4Cl$.

- ***Determination of Base Saturation in soil***

Base saturation was calculated using following equation.
Base Saturation= {(Ca) + (Mg) + (K)}/Cation Exchange Capacity*100

- ***Determination of hot water extractable Boron in soil***

Air dried, sieved 2g of soil sample was weighed into a plastic shaking bottle. Then 40 ml of distilled water was added, and it was kept for 6 hours in water bath. Next it was centrifuged, and 1 ml of filtrate put into the silicon flask. The filtrate was added with 10 ml of conc. H2SO4 and 10 ml of Carminic acid and swirled to mix well. Each flask was covered by using watch glass and kept 6 hours for color development. The samples were read against the blank, using 2cm cell in spectrophotometer under the wavelength of 610nm.

*2.6.2. Leaf Analysis*

- ***Determination of Nitrogen in leaf sample***

Finely grinded 0.2 g of plant material was weighed into digestion tubes. Then 0.4g of leaf catalyst was added into the tube. Tubes were placed on digestion block for one hour after adding 3ml of conc. $H_2SO_4$ acid. Then two drops of distilled water were added while transferring to the Kjeldahl flasks. Next the double distillation was done in Kjeldahl unit {(25ml of Boric acid ($H_3BO_3$) and 40ml of Sodium Hydroxide (NaOH). Finally, titration was done against 0.1 N Hydrochloric acid (HCl) until the solution turns to the crimson red colour.

- ***Determination of Total potassium, phosphorus, Magnesium, Sodium, Calcium and trace elements in leaf sample***

Finely grinded 0.2 g of plant material was weighed into digestion tubes. Then it was kept in muffle furnace overnight. Then one drop of distilled water and 0.2 ml of digestion mixture was added and placed on hot plate to evaporate. Next 10 ml of 0.05N HCl acid was added using a pipette. Then cap was covered with parafilm and shaked. Potassium was determined by Flame photo meter. Calcium, Magnesium and Trace elements were determined by using Atomic Absorption Spectrophotometer. Phosphorous in leaf were determined by Vando Molybdate yellow method with UltraViolet Visible Spectrophotometer at 425 nm wavelength.

## 3. RESULTS AND DISCUSSION

### 3.1. Effect of application of wood ash on soil pH

The soil pH is shown in Table 7. The soil pH values measured with distilled water varied significantly among treatments. The higher pH values can be seen in the plots treated with wood ash compared with inorganic mixture applied plots, it was due to the liming effects of wood ash. In contrast that inorganic fertilizer applied plots showed lowest pH values because of acidity created by nitrification of $NH_4^+$ ions from urea hydrolyses (Weaver, *et al.*, 2004). Any ammonium fertilizer when nitrified by nitrifying bacteria releases H+ ions to the soil solution as follows.

$$CO(NH_2)_2 + H_2O \longrightarrow NH_4COONH_4$$
$$NH_4COONH_4 + H_2O \longrightarrow (NH_4)_2CO_3$$
$$(NH_4)_2CO_3 \longrightarrow 2NH_4^+ + CO_3^{--}$$
$$CO_3^{--} + H_2O \longrightarrow H_2CO_3 + 2OH^-$$
$$2NH_4^+ + 6\,(O) \longrightarrow 2NO_2^- + 2H_2O + 4H^+$$
$$2NO_2^- + (O) \longrightarrow 2NO_3^-$$

Net acidity $2H^+$ per urea molecule i.e. $1H^+$ per N atom.

**Table 7**: Effect of treatments on soil pH

| Treatments | Soil pH $_{(water)}$ | Soil pH $_{(CaCl2)}$ |
|---|---|---|
| Wood ash (WA) (500kg/ha/yr) + Compost (20t/ha/yr) | $4.64^b$ | $4.20^a$ |
| Wood ash (WA) (1000kg/ha/yr) + Compost (20t/ha/yr) | $5.40^a$ | $4.39^a$ |
| Wood ash (WA) (500kg/ha/yr) + Refuse tea (20t/ha/yr) | $4.50^b$ | $4.05^a$ |
| Wood ash (WA) (1000kg/ha/yr) + Refuse tea (20t/ha/yr) | $4.35^b$ | $4.06^a$ |
| Current recommendation (VPLC880) | $4.10^b$ | $3.89^a$ |
| LSD | 0.711 | 0.515 |
| CV% | 5.575 | 4.491 |

Any process that leads to the release of H+ ions to the soil acidifies the soil because the soil pH which determines the degree of soil acidity is dependent on the concentration of H+ ions in soil solution, if not well buffered.

$$pH = -log10[H+]$$

Where H+ is the concentration of hydrogen ions expressed in moles per liter (Wickremasinghe, 1986).

### 3.2. Effect of application of wood ash on soil available P and K

The soil available P and K are shown in Table 8. Soil available phosphorous content did not vary significantly with treatments. However, higher values were observed wood ash applied plots with refuse tea, the sufficiency level of phosphorus content in the soil should be ≥ 20ppm.

Soil available potassium varies significantly among treatments. The concentration of the soil potassium in wood ash applied pots with compost significantly differs with other treatments especially with inorganic mixture applied plots. Zimmermann and Frey (2002) also showed that wood ash usually presents a relatively high concentration of potassium. The optimum level of soil available K for better growth of tea plant should be greater than 100 mg /kg K of soil. Therefore, K requirement can be fulfilled by application of 500 kg/ha/year of wood ash per hectare per annum with compost.

**Table 8**: Effect of treatments on soil available P and K

| **Treatments** | **Soil P (mg/kg)** | **Soil K (mg/kg)** |
|---|---|---|
| Wood ash (WA) (500kg/ha/yr) + Compost (20t/ha/yr) | 25[a] | 237[a] |
| Wood ash (WA) (1000kg/ha/yr) + Compost (20t/ha/yr) | 31[a] | 231[a] |
| Wood ash (WA) (500kg/ha/yr) + Refuse tea (20t/ha/yr) | 72[a] | 78[b] |
| Wood ash (WA) (1000kg/ha/yr) + Refuse tea (20t/ha/yr) | 55[a] | 72[b] |
| Current recommendation (VPLC880) | 29[a] | 62[b] |
| LSD | 52.43 | 29.06 |
| CV% | 44.57 | 7.69 |

### 3.3. Effect of application of wood ash on soil available Mg and Ca

The soil available Mg and Ca are shown in table 9. Soil available Mg varies significantly among treatments. The concentrations of the soil Mg in wood ash applied pots at 1000kg/ha/yr with either compost or refuse tea significantly differ with other treatments especially with inorganic mixture applied plots. Soil available Ca varies significantly among treatments. The concentration of the soil Ca in wood ash applied pots at 1000kg/ha/yr with either refuse tea significantly differs with other treatments especially with inorganic mixture applied plots. Rigau (1960) also stated that calcium and magnesium carbonate or oxides are present in comparatively large quantities in the wood ash. The optimum level of soil available Mg for better growth of tea plant should be greater than 60 mg /kg Mg of soil.

### 3.4. Effect of application of wood ash on soil Organic carbon content and CEC

The soil organic carbon content and soil CEC are shown in table 10. Not significant difference ($p \leq 0.05$) in organic carbon content was observed among treatments. Wood ash incorporation with either compost or refuse tea applied pots showed higher values. It may be due to soluble organic compounds in refuse tea. In the tea growing districts of Sri Lanka, the organic matter in general is reported to vary with elevation, between 1.5 to 2.0 percent carbon at low elevation and 3.0 to 6.0 percent carbon at high elevations (Krishnarajah, 1984). Therefore, application of wood ash with organic matter will be the best solution for improvement of organic matter content in soils in low and mid elevation of Sri Lanka.

**Table 9:** Effect of treatments on soil available Mg and Ca

| Treatments | Soil Mg mg/kg) | Soil Ca (mg/kg) |
|---|---|---|
| Wood ash (WA) (500kg/ha/yr) + Compost (20t/ha/yr) | 24[ab] | 126[b] |
| Wood ash (WA) (1000kg/ha/yr) + Compost (20t/ha/yr) | 34[a] | 183[b] |
| Wood ash (WA) (500kg/ha/yr) + Refuse tea (20t/ha/yr) | 33[a] | 351[a] |
| Wood ash (WA) (1000kg/ha/yr) + Refuse tea (20t/ha/yr) | 23[ab] | 190[b] |
| Current recommendation (VPLC880) | 17b | 145b |
| LSD | 3.217 | 103.20 |
| CV% | 18.16 | 18.73 |

**Table 10:** Effect of treatments on soil Organic carbon content and CEC

| Treatments | Soil O.C % | Soil CEC (meq/100g) |
|---|---|---|
| Wood ash (WA) (500kg/ha/yr) + Compost (20t/ha/yr) | 2.69[a] | 19.7[b] |
| Wood ash (WA) (1000kg/ha/yr) + Compost (20t/ha/yr) | 2.76[a] | 20.1[b] |
| Wood ash (WA) (500kg/ha/yr) + Refuse tea (20t/ha/yr) | 2.62[a] | 21.8a |
| Wood ash (WA) (1000kg/ha/yr) + Refuse tea (20t/ha/yr) | 2.76[a] | 22.1[a] |
| Current recommendation (VPLC880) | 2.25[b] | 18.0[c] |
| LSD | 0.231 | 1.528 |
| CV% | 3.18 | 2.69 |

The CEC of the soil in wood ash applied pots at refuse tea significantly differ with other treatments especially with inorganic mixture applied plots. Almost all tea growing soils in Sri Lanka belong to soil order Ultisols and Inceptisols (Mapa *et al.*, 1999) hence the presence of active clay fraction is poor throughout the profile. Mineralogical analysis performed for Ultisols and Inceptisols of the wet and intermediate zones indicates the dominance of kaolinite which comprised 80-90% and 40% among the total clay fraction respectively (Indraratne, 2009). Therefore, one of the major governing factors of the CEC of such soil is organic carbon content which is mostly pH dependent. Consequently, organic carbon has a higher influence on the CEC thereby to the pH buffering capacity.

### 3.5. Effect of application of wood ash on leaf N, P and K concentration

The N, P and K, content in mature leaf is shown in Table 11. Significant difference ($p \geq 0.05$) in N, P and K content in the mother leaves were observed among treatments. Wood ash incorporation with either compost or refuse tea applied pots showed higher values compared with inorganic fertilizer applied plots.

**Table 11**: Effect of treatments on leaf N, P and K concentrations

| Treatments | Leaf N % | Leaf P % | Leaf K % |
|---|---|---|---|
| Wood ash (WA) (500kg/ha/yr) + Compost (20t/ha/yr) | 1.42[ab] | 0.220[b] | 1.42[b] |
| Wood ash (WA) (1000kg/ha/yr) + Compost (20t/ha/yr) | 1.38[ab] | 0.225[ab] | 1.38[ab] |

| | | | |
|---|---|---|---|
| Wood ash (WA) (500kg/ha/yr) + Refuse tea (20t/ha/yr) | 1.49[a] | 0.260[a] | 1.49[a] |
| Wood ash (WA) (1000kg/ha/yr) + Refuse tea (20t/ha/yr) | 1.36[ab] | 0.235[ab] | 1.36[ab] |
| Current recommendation (VPLC880) | 1.32[b] | 0.240[ab] | 1.32[b] |
| LSD | 0.137 | 0.037 | 0.137 |
| CV% | 3.564 | 5.763 | 3.564 |

The literature on wood ash application to tea is limited. However, similar effects have been reported from a long-term field experiments conducted with different rates of N, K and dolomite to assess growth, soil-plant nutrient status and yield of tea (Sandanam *et al,* 1980).

### 3.6. Effect of application of wood ash on leaf Mg and Ca concentration

The Mg and Ca content in mature leaf are shown in Table 12. Significant difference ($p \geq 0.05$) in Mg content in the mother leaves were observed among treatments. Highest value was observed in wood ash 1000kg/ha/yr applied pots with refuse tea.

**Table 12:** Effect of treatments on leaf Mg and Ca concentrations

| **Treatments** | **Leaf Mg %** | **Leaf Ca %** |
|---|---|---|
| Wood ash (WA) (500kg/ha/yr) + Compost (20t/ha/yr) | 0.145[b] | 1.46[a] |
| Wood ash (WA) (1000kg/ha/yr) + Compost (20t/ha/yr) | 0.150[b] | 1.49[a] |
| Wood ash (WA) (500kg/ha/yr) + Refuse tea (20t/ha/yr) | 0.140[b] | 1.44[a] |
| Wood ash (WA) (1000kg/ha/yr) + Refuse tea (20t/ha/yr) | 0.180[a] | 1.46[a] |
| Current recommendation (VPLC880) | 0.180[a] | 1.61[a] |
| LSD | 0.029 | 0.396 |
| CV% | 6.596 | 5.526 |

## 3.7. Effect of application of wood ash on made tea yield

The variations of tea yield in relation to different treatments are shown in Table 13. Significant difference in yield was observed among treatments. Wood ash applied plots showed comparable yield with present TRI fertilizer recommendation. The highest made tea yield was obtained in wood ash applied pots at 1000kg/ha/yr with refuse tea.

Greenhouse studies at the University of Wisconsin-River Falls show alfalfa and barley yields from wood ash applications of 5-20 tons per acre to be significantly greater than those from commercial lime and fertilizer applied at rates recommended by soil test (Anon, 2013).

**Table 13:** Effect of treatments on made tea yield

| Treatments | Made Tea Yield (kg/ha) |
|---|---|
| Wood ash (WA) (500kg/ha/yr) + Compost (20t/ha/yr) | 2994[b] |
| Wood ash (WA) (1000kg/ha/yr) + Compost (20t/ha/yr) | 3117[ab] |
| Wood ash (WA) (500kg/ha/yr) + Refuse tea (20t/ha/yr) | 3127[ab] |
| Wood ash (WA) (1000kg/ha/yr) + Refuse tea (20t/ha/yr) | 3358[a] |
| Current recommendation (VPLC880) | 3026[b] |
| LSD | 289.1 |
| CV% | 3.332 |

## 4. CONCLUSION

Huge amount of wood ash is being removed from tea factories in Sri Lanka; there is still no efficient and proper way to reap the maximum benefit out of wood ash from tea factory. Therefore, the main objective of this study was to investigate the suitability of tea factory wood ash as a plant nutrient source for mature tea. According to the results obtained there is soil, leaf nutrient levels and yield improvement by the application of tea factory wood ash at 1000 kg/ha with refuse tea at 20t/ha/yr.

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