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The impact of unleached wood ash as a side dressing fertilizing material on growth and tuber yield of sweet potato (*Ipomoea batatas* L.)

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Abstract

Sweet potato (*Ipomoea batatas* L.) is amongthe world's most important and versatile food crops with high yielding potential of dry matter (DM) (vine and tuber) and tuber yield, but the crop's production remains low due to lack of fertilizers. The current study investigates the impact of applying unleached wood ash as a side dressing fertilizing material on growth and tuber yield of sweet potato. The Msasa (*Brachystegia specifomiis* Benth.) wood ash treatments (30, 50and 70g/plant) were applied on German 11 sweet potato cultivar. No ash and potassium sulphate were the negative and positive control treatments used, respectively. Measurements taken were number of tubers, fresh tuber weight, tuber DM, vine DM and tuber yield. Unleached wood ash gave highly significant ($P<0.001$) effect on all variables measured, except of number of tubers/plant where no significant ($F_{4,12} = 0.51$; $P=0.728$) effect was observed. Potassium sulphate significantly ($P < 0.05$) increased growth and tuber yield of sweet potato on all variables (except tuber number) more than the highest wood ash treatment (70 g). Highest DM% (tuber and vine) was produced at an optimum wood ash application of 50g/plant, while highest fresh tuber weight and tuber yield were obtained at 70g/plant. Based on the results, it is concluded that wood ash has potential to increase growth and tuber yield of sweet potato grown in poor soils; maximum vine and tuber DM% are attained at50 g/plant Msasa wood ash, while fresh tuber weight and tuber yield are attained at 70g/plant.

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Introduction

Sweet potato (*Ipomoea batatas* L.) is an important vegetable crop with roots that are sweet-tasting, starchy, and tuberous; with bushy vines that are consumed worldwide. Its nutritional value far exceeds yam, cassava and cocoyam (Onwueme, 1978). The shoots and young leaves of the plant are consumed by humans as vegetables in parts of Africa South of Sahara (ASS). The leaves are rich in vitamin A (beta-carotene) which is important in nutrition. Hence, the crop can serve as food security for many people in ASS. The tubers are boiled and served as meals.

The global production of sweet potato tuber yield trends indicated a decline from 130.47 million tons in 2004 to 107.64 million tons in 2009(FAO Statistical Database, 2011), while the production in China, having the largest share towards world production of sweet potatoes, also witnessed a decrease from 105.84 in 2004 to 81.21 in 2009 (Gopalakrishnan *et al*., 2011).In earlier times, sweet potato tuber yields in parts of Africa (5 t/ha) have been reported low due to diseases and pests (Gurr *et al*.,2016), and poor crop management as compared to Asia (16 t/ha) and South America (10 t/ha) (Onwueme and Sinha, 1991).In Africa South of Sahara, growth and fresh tuber yields are generally low as many rural farmers either apply no or inadequate fertilizers to their sweet potato crops. This has been attributed to lack of fertilizers (Mohamed, 1984).

The yield of sweet potato tubers is promoted by top dressing the crop with commercial fertilizers rich in K (Collins, 2000). Potassium sulphate is one of the inorganic (commercial) fertilizers which have K (Collins, 2000), and used as a side dressing. However, most soils used for sweet potato growing by many rural farmers in Zimbab we are sandy and acid. They lack such nutrients such as K and Ca in their soils. The farmers cannot afford to buy commercial fertilizers, especially top dressing fertilizers which are usually applied more than once to a crop during its growing period. The greatly needed commercial fertilizers are also not usually locally available (Turner and Chivinge, 1999), more especially potassium sulphate.

Unleached wood ash could be an alternative to the use of commercial fertilizers. Wood ash has a good acid-neutralizing capacity and supplies the soil with a range of mineral nutrients (Tamminen and Saarsalmi, 2013). Studies done showed that wood ash had potassium and calcium elements which could be used for tuber growth and liming purposes in impoverished soils (Campbell, 1990; FüzesI *et al*., 2015).A decrease in acidity and an increase in base saturation following the application of wood ash have been widely reported (Eriksson 1998; Saarsalmi *et al*., 2001;Ludwig *et al*., 2002). Schiemenz (2011) reported that the use of wood ash increases the uptake of P in low pH soils which then increases plant growth as well as yield. Demeyer *et al*. (2001) concluded that application of wood ash may increase yields of a range of crops, often associated with increased availability of Ca, K, Mg, P and trace elements such as Zn and Cu. Studies have shown that there are significant yield gains after applying wood ashes on nitrogen fixing plants such as groundnuts (White and Rice, 1993) and cowpeas (Awodun, 2007), but no trials have been done so far on the effect of applying wood as has a side dressing natural fertilizer on sweet potato growth and tuber yield. In addition, although there are studies which reported presence of macro and micro nutrients in different types of wood ashes, there is still a knowledge gap on how much to apply the Msasa wood ash to obtain optimum growth and tuber yield of sweet potato. Therefore, the study seeks to find out the effect of wood ash as a substitute for artificial fertilizers on growth and yield of sweet potato and to determine the optimum amount of wood which gives the greatest growth and tuber yield of the crop.

Materials and methods

Experimental site

The study was carried out in Chigora village, ward 28 of Makoni district, situated 55km South of Rusape town(coordinates*18° 32'* 6.9072'' S and 32° 8' 5.5140'' E.), Zimbabwe. In 2014; 2015 and 2016 annual rainfall received in the district was 650mm; 700mm and 780 mm respectively. The mean monthly temperature was 25; 24 and 24.2°C respectively. The soil is sandy loam, with a pH of 5.8.

Ash collection

Unleached ash was collected from fire places in August 2016 and same month in the following year (2017). Charcoal was sieved out to remain with ash only. The common trees used as fire wood in the area were the hard wood which was rich in K, Caand P as well as micronutrients. Msasa (*Brachystegia specifomiis* Benth.) was the only tree species chosen as the source of wood ash that was used in the current study. The collected wood ash was stored in a shade where no rain could leach it.

Biological material

The Germany 11 standard sweet potato variety commonly grown in the area was used. This cultivar has a spreading growth habit which has the ability to regenerate shoots so fast. The vines were used for the vegetative propagation of the Germany 11 standard sweet potato variety. The propagule was obtained from Marondera Grassland Research Station, Marondera (coordinates 18º 11′ 23″ S 31º 32′ 48″ E), Zimbabwe. It is a medium maturity variety which takes 140 days to reach physiological maturity. The tuber hasred peels and the rest of the interior part of the tuber (the flesh) has a whitish flesh which has a high starch and DM content. It is a rapid tuber bulking variety.

Treatments and experimental design

The Msasa wood ash treatments used were 30 g, 50 g and 70 g/plant. Additional treatments no ash application and 2 g/plant potassium sulphate as negative and positive control respectively. The treatments were replicated four times and arranged in a randomized complete block design (RCBD).

Land preparation and planting

The field was ploughed, disced, harrowed and ridged. Since the soil was loose owing to the deep ploughing done, ridging was done easily by use of hoes. The ridges were necessary for providing the developing roots with loose, friable soil which would allow expansion of tubers to their potential size and shape without restriction (Namo and Akinbola, 2016).Ridges allow drainage and aeration which are important requirements for successful tuber growth. The size of each plot was 9 m ridge length, with a height of 30 cm above the ground and a width of 40 cm at the base (Mvumi *et al.*, 2018).

The protocol for Mvumi *et al.* (2018) was followed on planting, with slight modifications on the planting dates. Vines of 30 cm length with approximately eight nodes were collected from established plants; from medium stem cuttings of mother stocks. Excess leaves were trimmed off from each cutting so that only eight leaves remained per each cutting.

Fertilization was according to the protocol of Department of Agriculture, Forest and Fisheries (DAFF) (2011). An amount of 100 kg Nitrogen (N), 90 kg Phosphorus (P), 200 kg Potassium (K) and 200 kg Calcium (Ca) were used. Planting was done on 4 November 2016 and 10 November in moist soil after receiving effective rainfall. Two thirds of the vine length was placed in the ground. Vines were planted at about a 45º angle into the ridges and at an in-row spacing of 30 cm. At this recommended plant spacing, 30 cuttings were required for a 9 m ridge row.

Application of experimental treatments

At week 6 after planting, Msasa wood ash treatments (30 g, 50 g and 70 g/plant) were applied as side dressing treatments. The second wood ash side dressing was applied at 12 weeks after planting. The negative control received no wood ash treatment. An amount of 2 g/plant potassium sulphate as a positive control was applied at the same periods when wood ash was applied (at 6 weeks and 12 weeks after planting) as a side dressing fertilizer. The experiment was repeated twice.

Tuber harvesting

Harvesting of tubers in all plots was done once, after 143 days from planting, when the crop was physiologically mature. Physiological maturity was noticed by the yellowing of the leaves, followed by abscission of some of the leaves. Visible cracks on the ridges were also noted. All tubers from each plot were harvested and gathered as per plot treatment.

Variables measured

The variables measured were: number of tubers per plant, tuber yield, tuber fresh weight, tuber DM, and vine DM per treatment. Measurements for the experiment were repeated twice and then averaged.

Number of tubers per plant

All plants from the net plots of the four plots of each treatment were harvested and the tubers were counted per plot and divided by number of plants per plot to get the mean tuber number/plant.

Fresh tuber yield

The mean fresh tuber weight was multiplied by the total plant population of 37037/ha to get tuber yield of each treatment/ha.

Fresh tuber weight

The total number of tubers/plot/treatment were weighed; the total tuber weight was then divided by total number of tubers obtained, to get mean tuber fresh weight. This means, this resultant weight was mean weight for each tuber).

Vine dry matter content

A sample of 2kg was taken from each plot of each treatment and the total was divided by the number of plots (4 plots/treatment) of that treatment as fresh vines. The average amount was weighed before sun drying for 2 weeks. The amount was re-weighed after sun-dying. The dry weight was then expressed as a percentage of fresh weight in order to get DM content of the sweet potato vines/plot.

Tuber dry matter content

A sample of 500g of sweet potato tubers was taken from each plot of each treatment and the total was divided by the number of plots (4 plots/treatment) of the treatment used. The average amount was sliced into small pieces and placed in an oven at 70^{o}C for 72 hours and then weighed again. The new weights were expressed as percentage of fresh weight to get the tuber DM content/plot.

Data analysis

Analysis of variance (ANOVA) using Gen Stat 14th version was used to detect significant differences between means. Means were further compared and separated using Turkey's HSD test ($P < 0.05$).

Results and discussion

Vine dry matter content

Application of wood ash showed highly significant ($F_{5;12} = 99.83$; $P<0.001$) effect on vine DM. The greatest vine DM content (23.25%) was obtained at a treatment of 50g/plant (Table 4.1). The increase of vine DM in the current study after wood ash application agrees with (Kooman, 1995) who mentioned that K increases leaf expansion and also delays senescence in leaves and thereby increases DM content in leaves and promote vine and leaf growth. In the current study, optimum application of wood ash was at 50 g. It proved that the K nutrient in wood ash is the one responsible for dry matter accumulation. Vine DM content increased with increase in the amount of wood ash applied up to 50 g/plant.

The results also showed that there were significant ($P <0.05$) differences among the treatment means, the treatment that received 70 g/plant wood ash had a significantly ($P >0.05$) lower DM content(20.75%) than of 50g/plant wood ash treatment (23.25%). The least application rate of 30g/plant wood ash had the least (19%) vine DM content but was significantly ($P < 0.05$) higher than the negative control (12.5%).Our results are in agreement with Awodun (2007) who found that the leaf values of N, P, K, Ca and Mg contents of cowpea (*Vigna unguiculata* L. Walp.) dropped at saw dust ash treatment of 10 t ha^{-1}, relative to 8 t ha^{-1}, resulting in the diminishing growth of leaves and branches. We postulate on the basis of this and earlier studies that there is a cut-off point for wood ash application in specific growth attributes. The values dropped at 10 t ha^{-1} ash relative 8 t ha^{-1} ash. This implies that there could be a cut-off point when using wood ash. This is because K level positively influences leaf area and duration, and vine DM content, up to a certain optimal level (Kareem, 2013).

Tuber dry matter content

The results from the current study showed that all wood ash treatments highly significantly ($F_{5;12}$ = 266.11; P <0.001) increased tuber DM content of Germany 11.Tuber DM content increased with increase in wood ash application. This proves that wood ash has an impact on the tuber DM content which contributes to tuber yield. Application of wood ash (which has K) increases leaf expansion area at the early stages of growth which then later increases tuber bulking (Kooman, 1995). Its application activates number of enzymes involved in photosynthesis, carbohydrate metabolism and assists in translocation of carbohydrates from leaves to storage roots (Bansal and Trehan, 2011).

Table 1. Means of the two experimental repeats of growth and tuber yield attributes of sweet potato (*Ipomoea batatas*) after application of Msasa (*Brachystegia specifomiis*) wood ash (g/plant) as a side dressing fertilizing material.

Treatment	Variables				
(Msasa wood ash (g/plant)	Tuber no./plant	Tuber DM%/plot	Vine DM%/plot	Fresh tuber wt (g)/tuber	Fresh tuber yield (t/ha)
-ve control (no wood ash)	2.8[a]	16.0[e]	12.3[e]	112.3[e]	7.3[e]
30	2.5[a]	18.5[d]	19.0[d]	132.3[d]	11.0[d]
50	2.5[a]	26.0[b]	23.3[b]	221.0[c]	18.3[c]
70	2.3[a]	24.3[c]	20.8[c]	265.3[b]	23.5[b]
+ve control (potassium sulphate)	2.3[a]	34.5[a]	25.5[a]	325.3[a]	26.5[a]
P	0.728	<0.001	<0.001	<0.001	<0.001
$LSD_{(0.05)}$	0.9	1.36	1.56	3.8	1.09
CV%	4.1	2.9	1.2	0.7	2.8

The highest amount of wood ash applied (70g/plant) gave significantly lower tuber DM content (24.3%) than the tuber DM content of 50 g wood ash (26.0%). However, the negative control (no wood ash) had the lowest DM content (16%). The results imply that addition of wood ash was proportional to increase in tuber DM up to 50 g/plant wood ash treatment level. The reason could be that Ca in wood ash could have raised pH to higher levels that led to reduced uptake of nutrients. Since wood ash also contains high amount of Ca (Erikson, 1998), if applied in excess, yields tend to decline. High supply of K, thus, could also reduce the tuber DM. This could be the reason why the highest wood ash treatment applied/plant had low vine and tuber DM content.

Number of tubers

There was no significant ($F_{5;12}$ = 0.51; P=0.728) effect of wood ash treatment means on tuber numbers (Table 4. 1). There were also no significant (P =0.05) differences among all the treatments used. Results did not show wood ash application level cut-off point. The results imply that wood ash application has no impact on tuber number, as a component of tuber yield. These results agree with a previous experiment which showed that wood ash K increases the size of the tubers and not the number of tubers (Trehan *et al.*, 2000). This was confirmed by Grewal and Singh (1980); Trehan *et al.* (2001) whose study revealed that K increases the size but not the total number of tubers. In general, rapid bulking potato varieties which produce large tubersizes respond more to K than do the varieties which produce small sized tubers, despite the different K fertilizer application levels which may be applied (Trehan *et al.,* 2000). The outcome could also have been due to varietal traits (Bazawit, 2015). Same study conducted by Bansal and Trehan (2011) had results which showed that varieties respond differently to K application in as far as yield parameters such as size and number of tubers are concerned.

Fresh tuber weight

Wood ash showed highly significant ($F_{5;12}$ = 5268.34; P<0.001) effect on fresh tuber weight.

The highest mean (265.25g) was recorded on the treatment that received 70g/plant wood ash. The negative control (no wood ash treatment) produced 112 g. There was 57.7% difference. The plots which received 50g/plant wood ash had a mean fresh tuber weight of 221g/tuber as compared to 265.25 g/tuber obtained from plots which received 70g/plant wood ash treatment. There was 16.65% increase. The results indicate that wood ash increases fresh tuber weight, with better response to higher amount of ash applied than the response of vine and tuber DM content. An amount of 70g/plant of wood ash gave higher fresh tuber weight than the tuber weight obtained after 50g/plant wood ash treatment. High photosynthesis rates influenced by Mg, which is also present in ash, could have influenced the growth, which finally contributed to high tuber fresh weight (Michael, 1985).

Fresh tuber yield

Wood ash also showed highly significant ($F_{5;12}$ = 520.67; P <0.001) effect on tuber yield. There were also significant differences among all treatment means for the yield of tubers. The negative control treatment had 7.5t/ha, while the treatment that received 30g/plant of wood ash had the fresh tuber yield of 11t/ha. At the application of 70g of ash per plant, the yield increased to 23.5t/ha. The plots with 50 g/plant wood ash had an average yield of 18.3t/ha.Results showed that fresh tuber yield/ha increased with increase in wood ash application; the fresh tuber yield increased up to 70 g/plant. The basis of these responses is on the role of wood ash to sweet potato. Wood ash supplies basic nutrients required such as K and P as well as Mg. Top dressing sweet potato with wood ash in the current study proved to increase tuber growth and fresh tuber yield. Taken together, they contribute to increase in tuber bulking size. Our results agree with (Kooman, 1995; Bansal and Trehan (2011). Patricia and Bansal (1999) reported that sweet potato has strict requirement for a balanced fertilization management, without which growth and development of the vines and tuber is diminished, or one attribute may be promoted while the other diminishes. For example, high K suppresses excessive leaf growth which affects vine DM content, resulting in higher tuber yield (Kareem, 2013).

Wood ash generally has a strong neutralizing and buffering capacity, which are the properties required for increased productivity of sandy soils. The hydroxyl ions formed as a result of the dissolution of the CaO, MgO, K_2O and NaOH in the ash neutralize the protons in the soil solution and those bound on cation-exchange sites in the soil. The released cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) displace the protons and Al^{3+} cations occupying cation-exchange sites (Erikson, 1998; Demeyer *et al*., 2001). So, by availing these nutrients in balanced quantities, wood ash increases tuber yield by increasing the size of tubers (Trehan *et al*., 2001). The increased yield of common beans (*Phaseolus vulgaris* L.) on an acid soil after wood ash application was attributed to both the liming effect and the relatively balanced proportions of CA, Mg and K (Zake and Nkwiine, 1982). Put together, the amount of fresh weight of tubers/plant contributes to yield level/ha.

Conclusion

This study confirmed that use of Msasa wood ash as a natural side dressing material for sweet potato has an impact on the growth and tuber yield of sweet potato. However, excess wood ash beyond optimum application levels proved to reduce tuber and vine DM content. Of all the wood ash treatments, highest dry matter (tuber and vine) was produced at an optimum wood ash application of 50g/plant. The study showed that there is a cut-off point for wood ash application, especially for DM content. The study has shown that there is no impact of wood ash on increasing tuber number, and that the fresh tuber weight and fresh tuber yield/ha can still increase after 50g/plant, up to 70g/plant wood ash treatment.

The study suggests that Msasa wood ash application on sweet potato used as a natural side dressing fertilizing material could be applied at 50 g/plant in order to get optimum vine DM and tuber DM, and 70g/plant for fresh tuber weight and tuber yield t/ha.

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