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The Effects of Neem Wood Ash on Soil Characteristics and Seedling Growth of Cowpea (*Vigna unguiculata* L. Walp)

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Authors' contributions

This work was carried out in collaboration among all authors. Author SA performed the experiment and carried out the statistical analysis. Author MZI designed and supervised the study. Author MS wrote the manuscript. Author MA approved the draft. Authors MK and ZRF managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The burning of wood in industrial activities discharge a large amount of wood ash and affecting on the environment. The effects of neem (*Azadirachta indica* A. Juss.) wood ash on seedling growth of cowpea (*Vigna unguiculata* L. Walp.) was recorded. The data reveals significant ($p<0.05$) effects of neem ash on the shoot length and seedling length of cowpea with the increase in the concentration of neem wood ash treatment up to 20%. The results also showed the significant ($p<0.05$) decrease in leaf weight ratio of cowpea as the wood ash concentration increase in substrate as compared to without ash treatment (control).

The effects of neem wood ash treatment on physical and chemical characteristics of soil including organic matter (%), pH of soil, calcium carbonate (%), chloride (meq/L), maximum water holding

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capacity (%) of soil, electrical conductivity (mS/cm), bulk density (g/cm^3), sodium and potassium content (µg/g) content of soil was found. The wood ash produced changes in physical and chemical soil characteristic viz. organic matter (%), pH of soil, water content (%), calcium carbonate (%), chloride (meq/L), maximum water holding capacity (%), electrical conductivity (mS/cm), bulk density (g/cm^3), sodium and potassium content (µg/g) content of soil.
Wood ash treatment affected physical and chemical poperies of soil which in turn results decreased seedling growth performance of cow pea.

Keywords: Cowpea; growth; neem wood ash; phytotoxicity; soil analysis; tolerance; tree.

1. INTRODUCTION

Large quantities of wood ash released from the wood industries and power plants resulting environmental pollution. The wood has high calorific value as a fuel and most widely used for high-grade charcoal [1]. Over a few decades a number of wood ashes are using in agricultural field. Demever et al. [2] reviewed the impact of ash released from the wood industry and power plants and consider its physical, chemical and mineralogical characteristics, effect on soil properties, availability of nutrient elements and on the growth and chemical composition of crops and trees, as well as its impact on the environment. The effects of wood ash on root growth, ash content, pod yield and nutrient status of okra (*Abelmoschus esculentum* L.) was reported [3]. There are few reports available on the use of fly ash for the improvement of crop production, biomass formation, yield, soil microbial activity, production of ceramic products, concrete manufacturing and land reclamation [4-13]. The risk of toxic effects and transfer of heavy metals, especially cadmium, from wood ash application in soil usually results bioaccumulation of cadmium in soil organism. The addition of wood ash in soil can raise soil pH and results in the of availability of trace elements as nutrient for plant growth. Wood ash residue has beneficial or harmful effects on the plant growth, composition of corn and seedlings growth, turfgrass, ground water quality and agricultural ecosystems were found influenced by soil application of ash [14-20]. In another studies, fly ash was found beneficial for the cultivation of palak, mung bean and chilli crops and showed immense potential to improve their growth and yield. The soil application of fly ash showed the potential for improving their production [21].

Land application of residuals from the forest industry can restore soil fertility, but few studies have assessed the effects of metal accumulation in plants [22]. Plant species selection is an important the success of rehabitation of fly ash dams [23]. The accumulated heavy metals in their above ground parts have the ability to reduce the potentially toxic concentrations of heavy metals from soil solution [24-27]. *Sida cardifolia, Chenopodium album* and *Phaseolus vulgaris* have been examined for metal accumulation grown in fly ash amended soil [28]. The significant influence of wood ash and nitrogen fertilization on crown biomass of *Pinus sylvestris* L. was studied [29]. Use of wood ash increased macronutrient content [30]. The heavy metal content in fly ash from biomass combustion, such as straw, wood and sludge, often needs reducing before the ash can be used as fertilizer for agricultural land or as a component in the production of construction materials [31]. The effect of wood ash applications at 0, 4, 8, 12 and 16 t^{ha-1} on soil chemical properties, N and P nutrient content and growth of cocoa (*Theobroma cacao*) seedlings was reported [32]. The effects of wood ash fertilization on soil chemical properties in three young Scots pine (*Pinus sylvestris* L.) plantations and a Norway spruce (*Picea abies* (L.) Karst.) plantation with different site fertility in southern Finland were studied and results showed wood ash induced pH increase of 0.6-1.0 pH units [33].

Azadirachta inidca A. Juss is multipurpose medicinal tree of family Meliaceae and found in tropical and subtropical areas of the world [34] and reached up to 15 m tall. It yields good timber and all parts of the plant are medicinal along with many phytochemical properties. Neem tree is cultivated in China, India, Bangladesh, Sri Lanka, Nepal, Maldives and throughout the warmer parts of Pakistan.

Fruit and seeds play a vital role in relieving protein malnutrition in many areas where animal protein cannot afford [35]. Cowpea, *Vigna unguiculata* (L.) Walp. (Fabales: Fabaceae) is an economically important legume believed to have originated from Sub-Saharan Africa [36,37].

The researchers are utilizing wood ash to use as manure to reduce the use of mineral fertilizer for the improvement in growth performance of agricultural crops and lessen the burden of pollution. Cowpea, *Vigna unguiculata* (L.) Walp. (Fabales: Fabaceae) is an economically important legume crop of the country and literature on the impact of neem wood ash on cow pea is scanty. The objective of the study was to evaluate the efficiency of the divine neem tree wood ash on seedling growth performance of an important legume crop cowpea as well as on physical and chemical characteristics of treated soil.

2. MATERIALS AND METHODS

The experiment was conducted in the green house at the Department of Botany, University of Karachi, Pakistan, during the month of August - September. The mean temperature was 28 to 32ºC and the relative humidity was 65-74%. *Azadirachta indica* A. Juss. (neem) and *Vigna unguiculata* L. Walp. (cow pea) was selected. Ash was made by burning the trunk and branches of neem. After burning, the wood ash was collected in jars and the experiments was conducted in pots. The seeds were sown in a garden soil at 1.00 cm depth in earthen pots and irrigated with tap watered daily. After two weeks same size seedlings were transplanted in plastic pots of 20 cm diameter and 9.8 cm in depth having the wood ash and without wood ash soils. The pots were filled up to 2/3 with soil. The neem wood ashes taken in this experiment were 4, 8, 12, 16 and 20% in following order, respectively.

For 0%, 0 gram of ash mixed with 100 gram of soil
For 4%, 4 gram of ash mixed with 96 gram of soil
For 8%, 8 gram of ash mixed with 92 gram of soil
For 12%, 12 gram of ash mixed with 88 gram of soil
For 16%, 16 gram of ash mixed with 84 gram of soil
For 20%, 20 gram of ash mixed with 80 gram of soil

The growth experiment was conducted in pots filled with garden loam soil. The healthy and certified seeds of cowpea (*Vigna unguiculata* L.) Walp. were obtained from the local market and were surface sterilized with 0.2% solution of sodium hypochlorite (NaOCl) for one minute to avoid any fungal contamination. Seven replicates for each concentration were taken. After mixing ash with the soil the seeds of cowpea were imbibed in water for half an hour for the purpose to break any type of seed dormancy. Ten seeds of cowpea were sown in each pot and pots were watered when required. Without wood ash treatment plant was used as control. The pots were reshuffled weekly to avoid light, shade or any other climatic factor. The plants were irrigated with tap water. After 40 days the plants were harvested. For dry weights, the root and shoots were dried at 80ºC for 48 hours in oven. The growth of cowpea was recorded in neem ash including their germination percentage, length of shoot and roots, number of leaves, leaf size.

Tolerance indices of seedlings were determined with the help of following formula.

Tolerance indices: Mean root length of wood ash treated seedlings / Mean root length of control seedlings X 100

The root shoot ratio, leaf weight ratio, specific leaf area, leaf area ratio was found by following formula;

Root/ shoot ratio = root dry weight / shoot dry weight
Leaf weight ratio = leaf dry weight / total plant dry weight
Specific leaf area ($cm^2\ g^{-1}$) = Leaf area / leaf dry weight
Leaf area ratio = Leaf area / Total plant dry weight

2.1 Soil Analysis

The physical and chemical soil analysis were also carried out. Reagent grade chemicals were used in chemical analysis preparation. Maximum water holding capacity (M.W.H.C.) of soil was determined by the method of Keen [38] while Bulk density was found according to Birkeland [39]. Calcium carbonate was determined by a method of acid neutralization [40]. Soil pH was determined by direct pH reading meter (Matter Toledo, MP 220). Chlorides were found through titration method. Determination of organic matter (%) was done according to Jackson [41]. Organic matter was converted into total organic carbon by using the conversion factor 1.724 (Organic matter / 1.724 = g organic carbon). Soil electrical conductivity (E.C. ms cm^{-1}) was determined by AGB 1000 (England) conductivity reading meter. Exchangeable sodium and potassium in soil was found to Richards [42].

2.2 Statistical Analysis

All the data was statistically analysed by Analysis of Variance (ANOVA) and Duncan Multiple Range Test (DMRT) at $p<0.05$ using personnel computer with software COSTAT version 3.

3. RESULTS AND DISCUSSION

The effects of different concentration (0, 4, 8, 12, 16 and 20%) of neem wood ash on seedling growth of Cowpea are illustrated in Table 1. Wood industries and power plants generate enormous quantities of wood ash [43] and influence on environment. In present study, neem wood ash have influenced on seedling growth performance of cowpea and on physical and chemical properties of soil. The higher concentration of wood ash a 12% decreased seedlings growth and biomass production of ow pea. The results showed highest shoot length (31.62 cm), root length (19.00 cm), seedling length (50.62 cm), leaf dry weight (0.502 g) and leaf weight ratio (0.616) of cowpea seedlings in control treatment (without ash treatment). The analysis showed significant ($p<0.05$) difference in shoot length and leaf area of cowpea with 4% treatment of wood ash. The lowest root length (12.2 cm), seedling length (31.7 cm) and leaf area (22.5 sq.cm) of cow pea was recorded with the increase in 20% wood ash treatment. Similarly, the effects of neem leaf, wood ash and their mixture on soil chemical composition and growth and yield of *Musa sapientum* L. was reported [44].

The seedlings growth performance of cowpea was tested for percentage of tolerance to different (4, 8, 12, 16, 20%) concentrations of neem wood ash (Fig. 1). The results showed that cowpea seedlings showed high percentage of tolerance (98%) at 4% of neem wood ash treatment. Cowpea seedlings showed better percentage of tolerance (93.42%) and (85.52%) at 12% and 16% of neem wood ash treatment, respectively. High percentage of decrease in seedling tolerance (64.47%) of cowpea was noted at 20% of neem wood ash treatment.

The addition of the wood ash play important role on the availability of nutrient elements as well as its impact on the environment. The neem wood ash treatment produced significant ($p<0.05$) effects on organic matter, pH of soil, chloride, electrical conductivity, sodium and potassium content of soil as compared to without neem wood ash treated soil (Figs. 2-4). The neem wood ash treatment produced less toxic effects on water content (%), calcium carbonate (%), maximum water holding capacity (%) of soil and bulk density (g/cm^3) of soil. E.C. correlate with the soil properties that affect plant productivity.

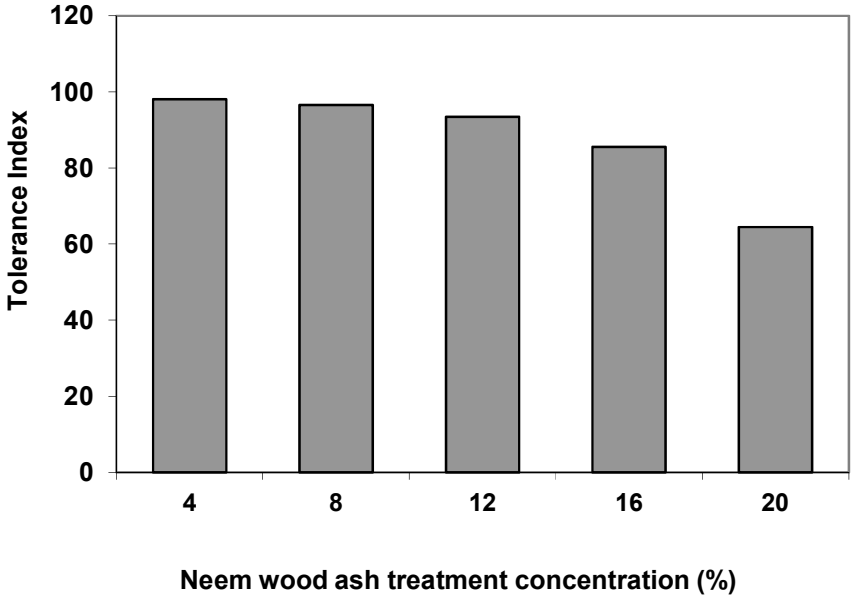

Fig. 1. Percentage of tolerance in cowpea seedlings using different concentration (4, 8, 12, 16 and 20%) of neem wood ash

Table 1. Effects of different concentration of neem wood ash on seedling growth of cow pea

Growth parameter	Neem wood ash concentration (%)					
	0	**4**	**8**	**12**	**16**	**20**
Shoot length (cm)	31.62c ±1.72	24.12b±1.50	17.0a± 0.41	22.0b±2.19	20.12a±1.01	19.5a ±1.44
Root length (cm)	19.00a ±4.45	18.60a ±1.8	18.25a ±3.2	17.7a±3.3	16.2a ± 0.2	12.2a ± 1.98
Seedling length (cm)	50.60a± 5.09	42.7ab±1.61	35.2a±3.5	39.7ab±4.96	36.4a±2.8	31.7a ±1.9
Leaf area (sq.cm)	37.30a ±6.59	61.5b±2.56	28.5a±7.75	28.1a±7.16	23.5a±2.58	22.5a ±5.42
Root dry weight (g)	0.080a±0.01	0.302a±0.03	0.177a±0.04	0.315a±0.04	0.252a±0.06	0.107a±0.02
Shoot dry weight (g)	0.202ab±0.03	0.305bc±0.1	0.185a±0.04	0.0322c±0.05	0.23abc±0.1	0.130a±0.02
Leaf dry weight (g)	0.502c±0.119	0.387bc±0.1	0.20ab±0.01	0.435bc±0.09	0.310abc±0.	0.137a±0.04
Total plant dry weight (g)	0.785bc±0.12	0.995c±0.10	0.56ab±0.01	0.072c±0.191	0.79ab±0.12	0.375a±0.07
Root / shoot ratio	0.435a ± 0.11	0.987b±0.01	1.03b ±0.17	0.991b± 0.037	1.13b± 0.29	0.834a±0.15
Leaf weight ratio	0.616b±0.063	0.384a± 0.1	0.37a ±0.03	0.394a±0.023	0.39a ± 0.02	0.35a ± 0.04
Specific leaf area (cm^2g^{-1})	85.23ab±25.2	169.8ab±36	148.5ab±44	61.73a±13.96	79.67ab±7.9	187.34b±60
Leaf area ratio	48.70a ±9.56	64.51a±14.1	59.59a±20.9	24.99a±6.13	30.82a±4.09	65.17a±22.5

Symbol used. ± = Standard Error. Values followed by the same letters in the same row are not significantly different ($p<0.05$) according to Duncan's Multiple Range Test

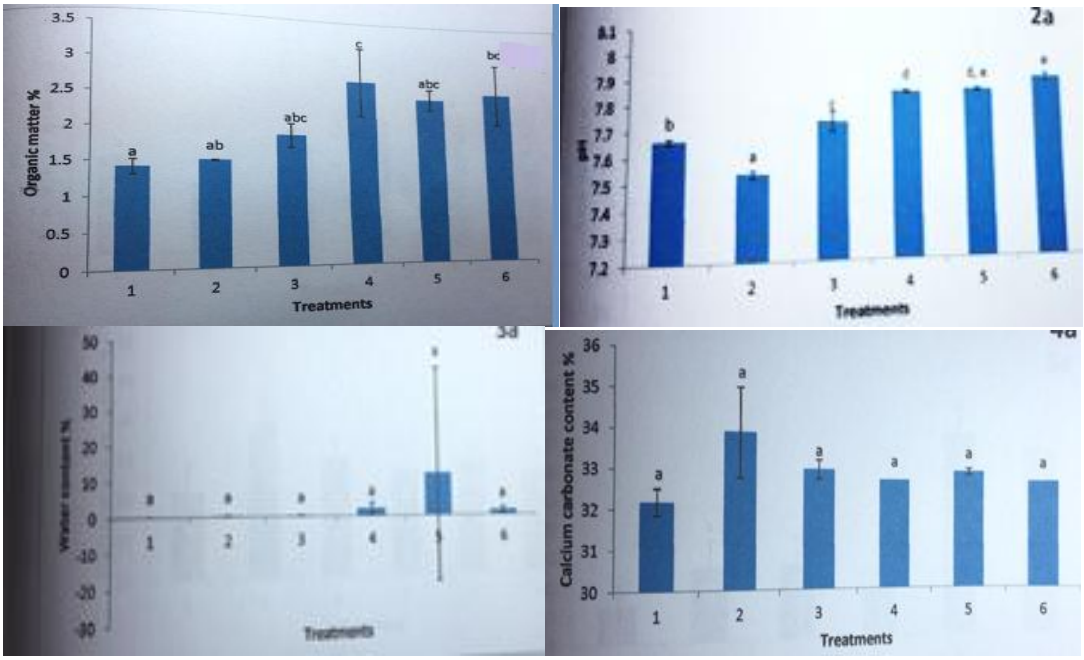

Fig. 2. Effects of neem ash on organic matter (%), soil pH, water content (%), calcium carbonate (%) content of soil

Symbol used: Neem wood ash treatment 1=0%, 2=4%, 3=8%, 4= 2%, 5=16%, 6=20%. Statistical significance determined by analysis of variance. Number followed by the same letter on the same bar are not significantly different, according to Duncan's Multiple range test at P<0.05

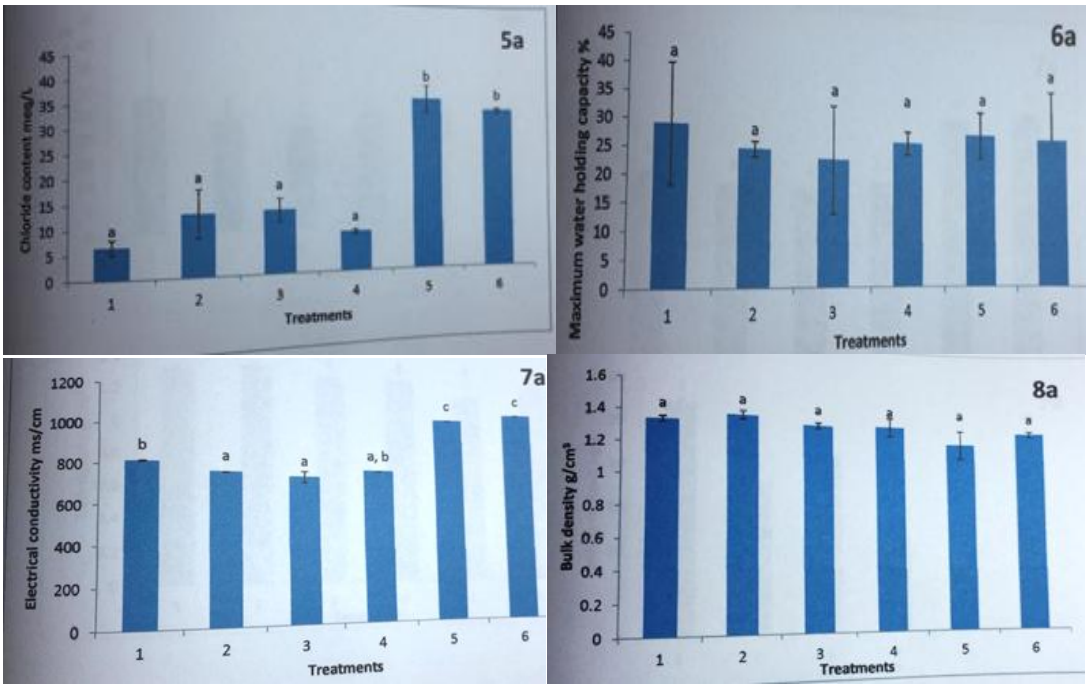

Fig. 3. Effects of different concentration of neem wood ash on chloride (meq/l), maximum water holding capacity (%), electrical conductivity (mS/cm) and bulk density (g/cm^3) of soil

Symbol used: Neem wood ash treatment 1 = 0%, 2 = 4%, 3 = 8%, 4 = 2%, 5 = 16%, 6 = 20%. Statistical significance determined by analysis of variance. Number followed by the same letter on the same bar are not significantly different, according to Duncan's Multiple range test at P<0.05

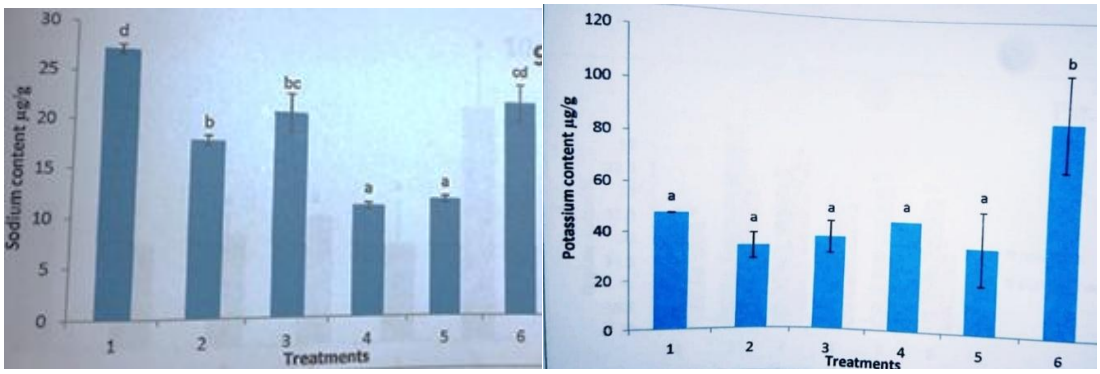

Fig. 4. Effects of different concentration of neem wood ash on sodium and potassium contents of soil

Symbol used: Neem wood ash treatment 1 = 0%, 2 = 4%, 3 = 8%, 4 = 2%, 5 = 16%, 6 = 20%. Statistical significance determined by analysis of variance. Number followed by the same letter on the same bar are not significantly different, according to Duncan's Multiple range test at P<0.05

The changes in chemical and physical and properties of soil can limit plant growth in ash amended soil deposits. High soil pH and high soluble salt concentrations responsible for nutrient deficiencies for plant. The physical include restriction of root growth due to natural compaction of fine ash particles formation of solid cemented layers due to the pozzalanic nature of some ashes [45]. The ash application proved to have an important and long lasting effect on soil organic matter content. The increased pH due to ash fertilization together with nutrient input from the ash most likely stimulated soil organic matter turnover [46]. Soil pH and base cations over time after application of wood ash on forest soil observed [47]. In present study, the wood ash treatment significantly increased soil pH at 20% wood ash treatment and agree with the findings of Qin et al. [48] who reported that wood ash application increases pH of the soil.

A significant difference in sodium and potassium content by different concentration of wood ash was found. Neem ash treatment at 20% significantly increased potassium content of soil (Fig. 4). The wood ash has been identified a significant increase in K content and soil solution chemistry in forested catchment area was found due to wood ash application at the rate of 3 tonnes/ha [49,50].

4. CONCLUSION

Concluded from the present studies, that the treatment of neem wood ash at different level (4, 8, 12, 16, and 20%) affected seedling growth and biomass production of cow pea as compared to control (without ash treatment). The neem wood ash treatment at 4% significantly ($p<0.05$) affected shoot and seedling length performance of cowpea. An increase in ash concentration at 16% significantly affected shoot dry weight of cowpea. The treatment of wood ash produced less effects on specific leaf area and leaf area ratio. The wood ash treatment also influenced on the level of physico-chemical properties of soil as compared to without wood ash treatment. The factors were the low percentage of Maximum Water Holding Capacity and bulk density of neem wood ash treated soil. While, results indicated the concentration of wood ash at 20% increased organic matter (%), soil pH, calcium carbonate (%), chloride, electrical conductivity and potassium content of soil. Low Maximum Water Holding Capacity of soil and bulk density of neem wood ash treated soil noted.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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