The forms of plant nutrient elements in Australian native plant ash derived from several species

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Wildfires and prescribed fires burn many thousand of hectares of forest annually (Ulery et al., 1996). The intensity of forest burning is related to weather conditions, amount of fuel available and the condition of the fuel. Ash derived from forest fires is generally an alkaline material with pH ranging from 9.0 to 13.5 (Khanna et al., 1994) and may contain substantial amount of plant nutrients. The aim of this study was to determine the properties of ash from several Australian native plant species.

Ash was created by burning plant materials from several plant species. Ash properties were studied by several techniques. The pH was determined in a 1:5 deionized water extract. The samples were analyzed for bicarbonate extractable P (Bic P) (Colwell, 1963) and the amounts of carbon and nitrogen were determined on an Elementar CNS (Vario Macro) analyzer. Ash colour was determined using a Munsell Color Chart (Munsell Color Co., 1998). Specific surface area (SSA) was measured using a Micrometrics Gemini 2375 instrument with VacPrep 061 using a five point BET method with N_2 as the absorbate. The water-soluble elements in ash were determined using Association of Official Analytical Chemistry (AOAC) standard methods (AOAC 1975). The chemical composition of ash was determined with a PE ELAN 600 inductively coupled plasma – atomic emission spectroscopy (ICP-OES) instrument (Perkin-Elmer, Norwalk, CT, USA) after perchloric acid digestion. Conventional XRD was conducted on a Philips PW3020 diffractometer with a diffracted beam monochromator (CuKα, 50kV, 20mA). Powder samples were scanned from 4 to 70^o 2θ, using a step size of 0.02^o 2θ and a scan speed of 0.04^o 2θ sec^{-1}. SXRD analysis was performed at the Australian Synchrotron where powder samples were mounted into glass capillaries with a 1.0Å wavelength set for this analysis in order to provide a high peak/background and adequate resolution for identifying minor constituents. The composition and morphology of plant ash was examined by scanning electron microscopy (SEM) and energy dispersive X-ray spectrometry (EDS) using a JEOL 6400 instrument. Samples for SEM analysis were placed on metal stubs and carbon coated before analysis.

The seven Australian native plants used for the study: silver wattle (*Acacia retinodes*), prickly moses (*Acacia pulchella*), wandoo/white gum (*Eucalyptus wandoo*), red gum or marri (*Corymbia calophylla*), grass tree (*Xanthorrhoea pressie*) jarrah (*Eucalyptus marginata*), and harsh hakea (*Hakea prostrata*) are major constituents of some native forest in Southwest Australia. A key to the materials investigated, abbreviations used and their properties are given in Table 1.

Table 1. The nomenclature and some properties of plant ash used for the experiment.

Key	Explanation	Ash %	Ash Color	SSA (m^2/g)	pH (1:5)	EC (1:5) (μS/cm)	Bic P (mg/kg)
SW	Silver wattle wood ash	1.72	G1 8/N	5.8	13.8	1895	144.9
SL	Silver wattle leaf ash	3.39	G1 5/N	4.2	12.8	1385	197.9
PM	Prickly moses leaf and twig ash	2.81	G1 4/N	8.3	13.1	847	198.8
WW	Wandoo wood ash	3.07	2.5Y 7/2	9.2	13.6	1512	175.5
WL	Wandoo leaf ash	3.02	G1 5/N	2.4	13.3	1431	31.9
RW	Red gum wood ash	4.71	G1 7/N	2.4	13.8	2323	183.1
RL	Red gum leaf ash	4.07	G1 6/N	2.5	13.4	1837	29.8
GT	Grass tree leaf ash	3.40	G1 3/N	2.7	13.5	2286	144.7
JL	Jarrah leaf ash	3.27	2.5Y 6/2	2.9	13.2	1898	196.0
HH	Harsh hakea leaf and twig ash	4.01	G1 4/N	7.7	12.3	1629	163.5

Ash percentage ranges from 1.7 to 4.7 % for the complete combustion of the plant materials (leaf, twig, wood, etc). Specific surface area of the ashes ranges from 2 to 9 m^2/g indicating that the particles of ash (crystal) are very small (micron size) and they are likely to be quite reactive in soil. The ashes are alkaline, pH ranging from 12.3 to 13.8. Available phosphorous (Colwell –P) in the ashes ranged from 29 to 198 mg/kg and EC values were high for all the ashes, indicating that the ashes contain substantial amounts of soluble salts. Minerals present in the ashes include calcite, fairchildite, nesquehonite, sylvite, lime, scolecite, quartz (dust), portlandite, periclase, hydroxyl-apatite and wilkeite (Figure 1).

Mean carbon and nitrogen concentrations in raw plants and ashes are presented in Figure 2. The amount of carbon was above 40% for all the raw plant materials and significantly reduced to below 15% for their ashes where carbon is mostly present as carbonates. Burning plants resulted in loss of most nitrogen with low nitrogen concentrations in ash. Plant ashes generally contain little nitrogen (Khanna et al., 1994) especially when the combustion of the fuel is nearly complete (Raison et al., 1985).

Scanning electron microscopy and associated X-ray spectra of particles in SW and SL ashes shown in Figure 3 illustrate the diverse particle sizes, shapes and compositions present in this material. Apart from calcite crystals, most grains seen in the micrographs are K and Mg-rich aggregates often micron-size particles with chlorine and commonly also containing a little P, Fe and S. These results indicate the complex nature of ash, with a high diversity in the composition, shape and size of particles.

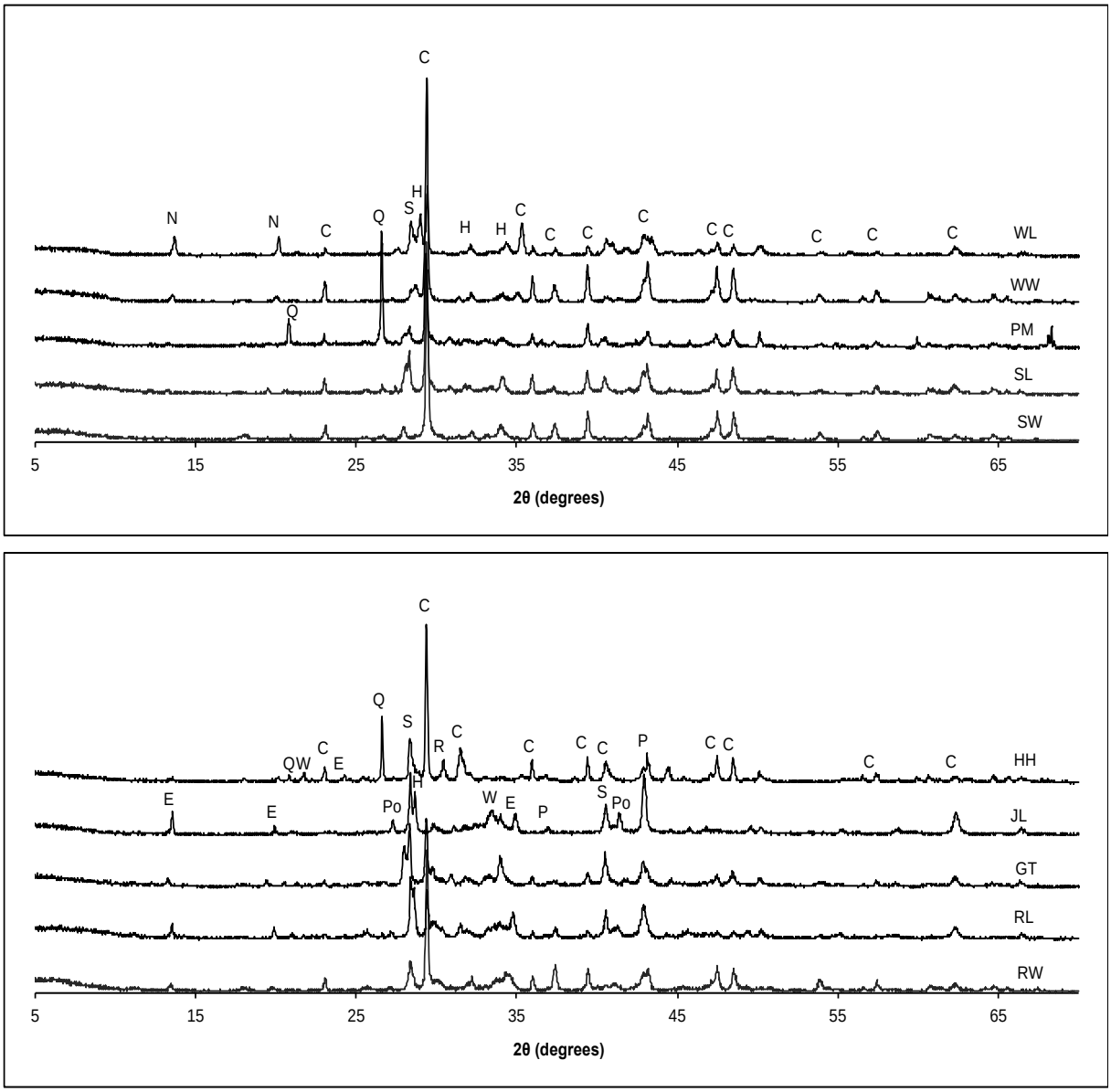

Fig 1. Conventional XRD patterns for native plants ash (F=fairchildite ($K_2Ca(CO_3)_2$), N=nesquehonite ($MgCO_3.H_2O$), C=calcite ($CaCO_3$), S=sylvite (KCl), H=hydroxyl-apatite ($Ca_5(PO_4)_3(OH)$), L=lime (CaO), E=scolecite ($CaAl_2Si_3O_{10}.3(H_2O)$), Q=quartz (SiO_2), W=wilkeite ($Ca_5((P, S, Si)O_4)_3(OH,CO_3)$), Po=portlandite ($Ca(OH)_2$) and P=periclase (MgO).

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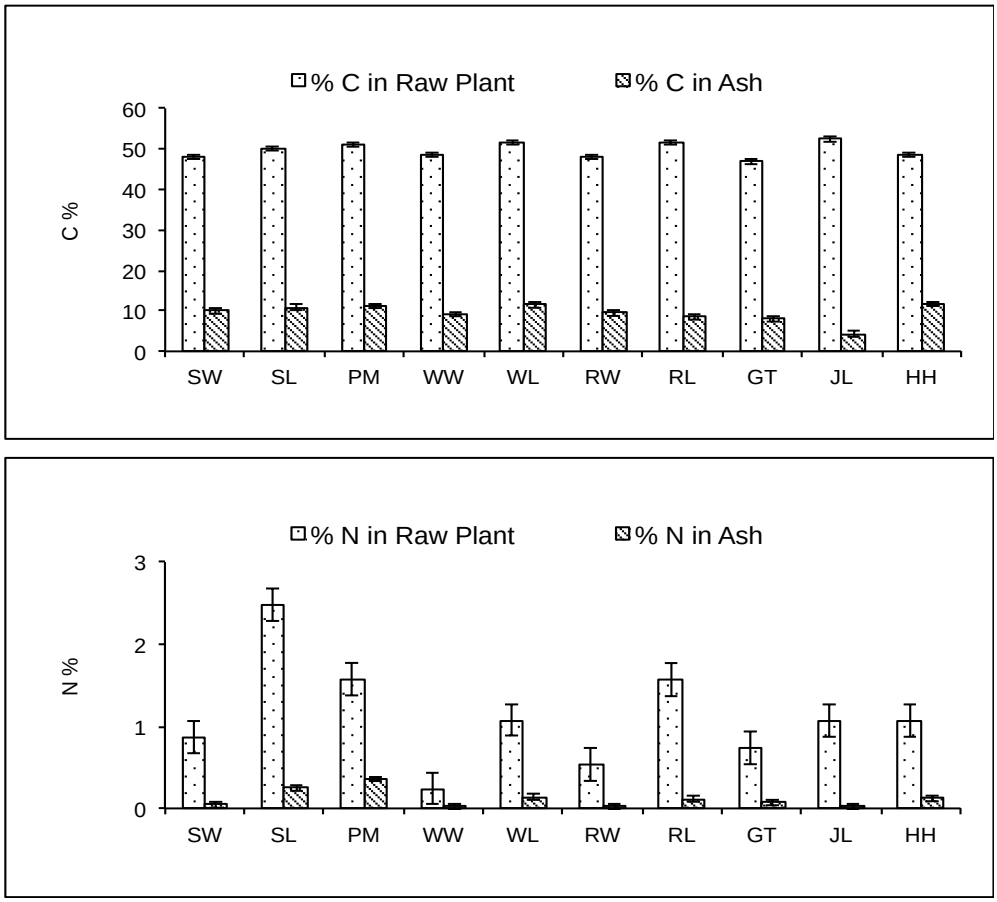

Fig 2. Mean values of carbon and nitrogen concentrations (%) of native plants (raw) and their ash.

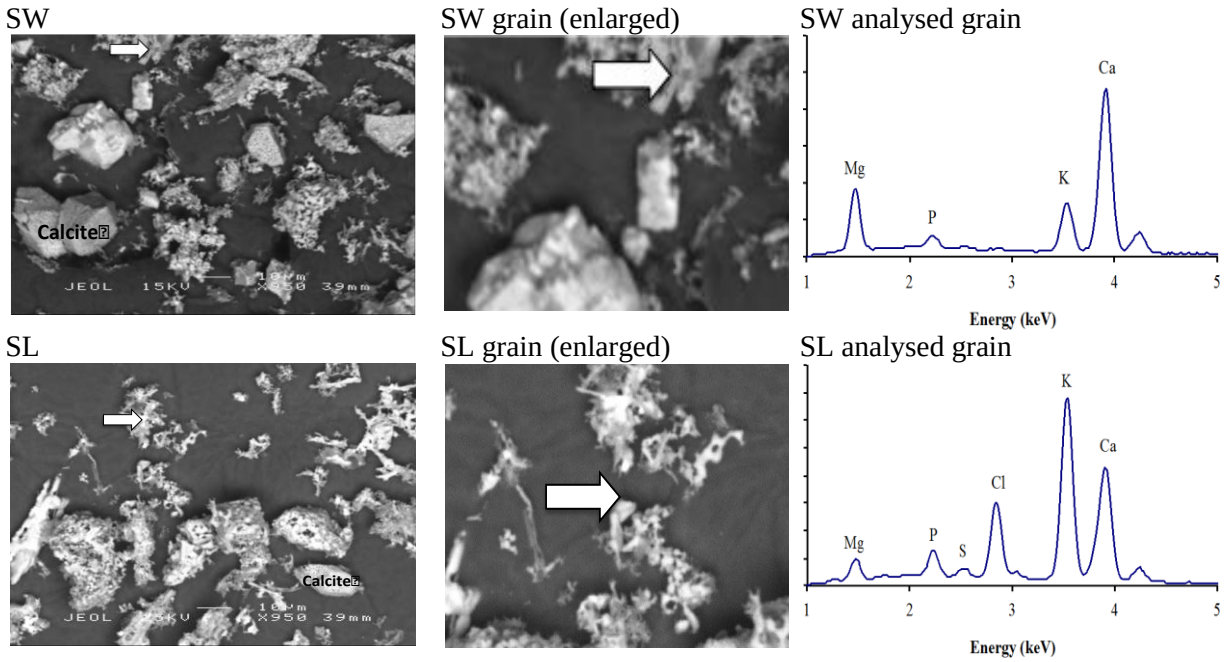

Fig 3. Scanning electron micrograph (SEM) and X-ray spectra of the indicated particles for SW and SL ash. Large calcite crystals are present in SW ash and the indicated area probably contains micrometric crystals of fairchildite and periclase. The aggregated micrometric crystals for SL ash probably include fairchildite, sylvite, periclase and apatie.