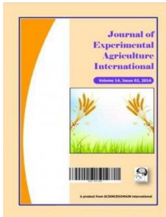

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Wood Ash as a Corrective and Fertilizer in the Cultivation of Mombaça and Massai Grass in Oxisol

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Authors' contributions

This work was carried out in collaboration between all authors. The authors EMBS and TJAS designed and wrote the protocol for the experiment. The authors AWC, HGF and PFR conducted the experiment and wrote the first draft of the manuscript. The authors LGAD and HHFS discussed the results, corrected and improved the writing of the manuscript in Portuguese and English versions. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this work was to estimate the yields of *Panicum maximum* cv. Mombaça and *Panicum maximum* cv. Massai in response to the plant ash doses in Oxisol. The experiment, following a completely randomized design, was conducted in a greenhouse and arranged in a 5x2 factorial design, which included 10 treatments and five replications, constituting 50 experimental plots. The treatments involved the addition of five plant ash doses (0, 8, 16, 24 and 32 g dm^{-3}) and two *Panicum* species: *Panicum maximum* cv Mombaça and *Panicum maximum* cv Massai. The experimental unit was a soil-filled container, 5 dm^3 in capacity. The characteristics assessed included: plant height, number of tillers, chlorophyll index and shoot dry mass. The plant was cut at a height of 5 cm from the soil surface. The findings were submitted to the analysis of variance and

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when significance was noted, the data were submitted to the Tukey test and regression analysis using the statistical program SISVAR. In terms of the soil pH, a notable effect was recorded for the vegetable ash doses applied to the soil, which exert a corrective effect on the soil. Plant height and number of tillers were the variables that revealed significance for the interaction between the *Panicum* cultivar and plant ash doses at 35 days after plant emergence. The soil ash induced the greatest levels of chlorophyll and dry mass of the aerial parts, registering a spurt in the dry mass of the aerial parts for both forages, signifying that the management performed with the vegetable ash favored the growth and yield of the Mombaça and Massai grasses.

Keywords: Alternative fertilizer; biomass burning; Panicum maximum.

1. INTRODUCTION

The Brazilian Cerrado is characterized by soils that have naturally poor fertility and low base saturation linked with high saturation through aluminum; however, even if the soils have strong physical features, the crops can be affected by the inadequate water supply in the dry spells typical of this region.

The principal pastures cultivated in this biome are the grasses belonging to the *Brachiaria* and *Panicum* genus because of their strong capacity to adapt to the environment [1]. As the practices of soil grazing and fertilization continue to be in use in the pastures to a small degree, they characterize an extractive exploitation system, which is the chief cause for pasture degradation [2,3].

Soils drew from the arable regions normally experience some degree of fertility imbalance, inducing nutritional deficiencies that arise from the intensive and uninterrupted cultivation. Thus, the soil fertility rectification is generally done employing chemical fertilizers, which are acquired from exhaustible origins [4].

In the agricultural sector, the basic requirements for economic success depend upon the forage quality, yield, and low production costs. Therefore, the application of industrial waste in agriculture appears to be a viable substitute to minimize the fodder production costs, besides the ecological allotment of a part of the waste industry, which becomes an environmental issue [5,6], when not suitably handled.

An additional and significant feature supporting the utilization of this residue is the rising expenditure of the acquisition and application of mineral fertilizers, and the producers, therefore, prefer to seek suitable substitutes for fertilization, to minimize the costs and maximize the productivity [7,8].

The ash produced by burning the plant biomass emerges as a residue with the strong potential as a soil corrective and fertilizer, as its qualitative and quantitative constituents depend on the biomass used and temperature of carbonization [9].

Fertilizers affect the soil fertility by lowering the soil acidity by its high concentration of the Ca and Mg oxides, hydroxides and carbonates [10] (Ca, Mg, and K) [11] and appreciable quantities of basic cations like Ca, Mg and K [11].

Thus, progress in research utilizing vegetable ash as a fertilizer is expected, in light of the estimations and the proper implementation of its management. Therefore, the applications made based on technical recommendations and by correctly relating the vegetable ash dosages with the soil characteristics and traits of each culture, contribute towards the effective rise in the plant yield.

Therefore, this study aimed at evaluating the development of *Panicum maximum* cv. Mombaça and *Panicum maximum* cv. Massai in response to the plant ash doses applied in the Oxisol.

2. MATERIALS AND METHODS

The experiment was performed in a greenhouse situated in a North-South direction, extending across a total area of 450 m^2 and located at latitude 16º 27'49 " South, and longitude 54º 34'47 " West, at an altitude of 284 m, in Rondonópolis - Mato Grosso, Brazil.

The soil used in the experiment was collected in an area under Cerrado vegetation from the layer of sandy loam at 0 - 0.20 m depth of the Oxisol [12], which had been sieved through a 4 mm mesh for the experimental plots. A soil sample was sieved through a 2 mm mesh for chemical and granulometric characterization (Table 1) according to [13].

Table 1. Chemical and granulometric analyzes of the oxisol collected in an area under cerrado vegetation, Rondonópolis-MT

pH		P	K	Ca+Mg	Ca	Mg	Al	H	OM	Sand	Silt	Clay
H_2O	$CaCl_2$	mg dm^{-3}			cmol$_c$ dm^{-3}				g dm^{-3}		g Kg^{-1}	
4.8	4.0	1.4	23	0.6	0.4	0.2	0.8	5.4	10.7	423	133	444

P = Phosphorus; K = Potassium; Ca = Calcium; Mg = Magnesium; Al = Aluminium; H = Hydrogen; CTC = Cation exchange capacity; OM = Organic matter; V = Base saturation; m = Aluminum saturation

Table 2. Chemical characterization of the wood ash

pH	PN	N	P_2O_5	K_2O	Zn	Cu	Mn	B	Ca	Mg	S	Si
(H_2O)	%						g Kg^{-1}					
11.8	25	0.25	48.5	16.6	0.13	0	0.5	0.2	37.5	28.5	2.8	187.0

N= Nitrogen; P_2O_5 = Phosphorus pentoxide; K_2O = Potassium oxide; Zn = Zinc; Cu = Copper; Mn = Manganese; B= Boron; Ca = Calcium; Mg= Magnesium; S = Sulphur; Si= Silicon

The completely randomized experimental design was adopted, arranged in a 5x2 factorial scheme, with 10 treatments and 5 replications, amounting to a total of 50 experimental plots, represented by plastic containers, each with 5 dm^3 soil capacity. The treatments included five doses of plant ash (0, 8, 16, 24 and 32 g dm^{-3}) and two Panicum species: *Panicum maximum* cv Mombaça and *Panicum maximum* cv Massai.

The *Panicum maximum* cv Massai is a natural hybrid of *Panicum maximum* and *Panicum infestum*. This grass is perennial, has a habit of growing cespitose, with thin leaves (1 cm) and decumbent, deep roots and the average height of the plants of 0.65 m. Dry matter production may reach 21.3 Mg ha^{-1} $year^{-1}$, with a morphological composition of 75% of leaves, and 14% of stalks [14].

The *Panicum maximum* cv. Mombaça is a grass that forms clumps up to 1.65 m high and leaves brittle. The stems are slightly purplish. The dry matter production is 15 to 20 Mg ha^{-1} $year^{-1}$ [15].

In the present study, the ash utilized was drawn from the biomass being burned for the brewery boilers and analyzed as a fertilizer (Table 2), according to [16].

After collecting the soil, it was sieved and conditioned in pots of 5 dm^{-3} capacity. Then the treatments (vegetable ash doses) were incubated for a 20-day period for the soil corrective reactions to occur. During the incubation period, the soil was maintained at 80% of its maximum water retention capacity. Once the vegetable ash in the soil completed the incubation period, the pH analysis ($CaCl_2$) was performed, and 10 cm^3 of the soil sieved through a 2.0 mm mesh was collected [13].

Seeding was performed by sowing 15 seeds per pot at 2.0 cm depth. Two slabs were done at 4 and 10 days after emergence (DAE) of the plants, based on vigor, homogeneity, and size. Thus, after the first thinning ten plants remained per pot, while after the second thinning only five plants were present per pot.

Employing the gravimetric method, the maximum soil water retention capacity was estimated in the laboratory. The pot capacity (maximum soil water retention capacity) was calculated following the method described by [17]. Throughout the course of the experiment, the humidity was maintained at 60% of the maximum water retention capacity of the soil.

Nitrogen fertilization was performed using 200 mg dm^{-3} (urea source) to establish the culture in all the experimental plots. The doses were given as three equal applications, at 10, 15 and 20 days after emergence, respectively. For fertilization utilizing micronutrients (boron, copper, zinc and molybdenum) the doses were 1.39; 2.61; 2.03; and 0.36 mg dm^{-3}. [18]. The present study revealed that the amount of boric acid, copper chloride, zinc chloride and sodium molybdate, respectively.

The findings for the plant growth and development were analyzed 35 days after emergence, at which time the variables plant height, number of tillers, chlorophyll index and dry mass of the shoot were assessed. Plant cutting was done at 5 cm above the soil surface.

The data were submitted to the analysis of variance by the F test and, when significance was noted, they were submitted to the Tukey test (qualitative variables) and regression analysis (quantitative variables) both with 5% of the probability of error, utilizing the statistical program SISVAR [19].

3. RESULTS AND DISCUSSION

From the analysis of variance, the interaction between the Panicum cultivars and the vegetable ash doses showed significance at 35 days after the emergence of the plants, for the variables plant height and number of tillers. A significant isolated effect was evident for the vegetable ash doses and other variables.

The soil pH revealed a significant effect in isolation, only for the vegetable ash doses, post the incubation period, adjusted to the quadratic model of regression (Fig. 1). The soil attained a maximum pH of 7.02 in response to the vegetable ash dose of 24.88 g dm^{-3}, thus authenticating its ability to lower the soil acidity, confirming that the vegetable ash was efficient as a soil corrective [20,9,21].

The action of the vegetable ash as a soil corrective was clearly evident and the vegetable ash doses notably improved the soil pH. The rise in the soil pH due to the vegetable ash occurred within the range accepted as appropriate for most crops. [16], confirmed that the rise in the pH units took place according to the increase in the vegetable ash doses, thus corroborating the findings of Ferreira et al., (K_2CO_3) and the reaction with the soil H + (K_2CO_3).

The capability of the ash as a corrective is possibly due to the high alkalinity, neutralization properties and presence of Ca, Mg and K carbonates in the vegetable ash [22], proven by the increased yield and soil pH correction with its application. These results concur with those reported by [23,24,7,25].

Plant height was strongly affected at the 5% probability level by the F test, via the interaction between the cultivars and vegetable ash doses (Table 3). The maximum height (89.4 cm) attained for the cultivar Mombaça was observed for the 8 g dm^{-3} dose of the vegetable ash, showing no statistical difference between the 16 and 24 g dm^{-3} doses.

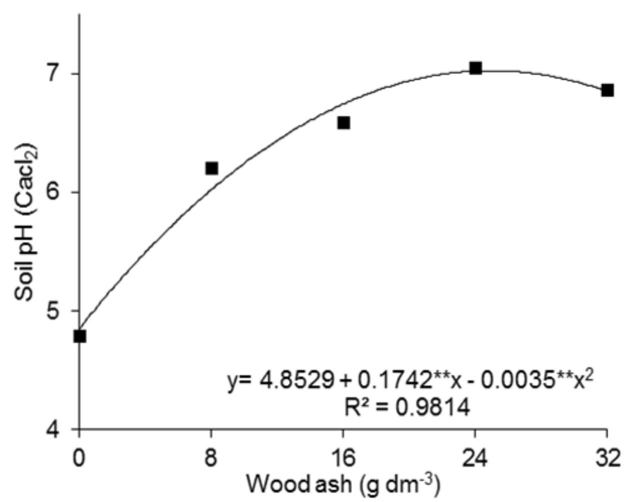

Fig. 1. pH of the Oxisol subjected to doses of wood ash after the incubation period of 20 days for the cultivation of Mombaça and Massai grass.
*** significant at 1% probability.*

Table 3. Height of Mombaça grass and Massai grass submitted to doses of wood ash in Oxisol

Cultivars	Plant height (cm)				
	Wood ash (g dm^{-3})				
	0	**8**	**16**	**24**	**32**
Massai	27,4 A	72,6 B	66,2 B	65 B	67,6 B
Mombaça	31,8 A	89,4 A	86,6 A	81,8 A	81 A

Means followed by the same letter do not differ in the column by the Tukey test up to 5% probability

Under these circumstances, it must be noted that the height difference between the cultivars may have a bearing on the morphological characteristics of each cultivar, where the Mombaça grass is genetically endowed to reveal an erect and taller posture when compared to the Massai grass. It is likely that this fact favored the highlight of this forage in height [26].

The splitting of the plant ash doses for each of the Panicum cultivars exerted a strong effect, with adjustment to the quadratic regression model. The plant ash doses of 20.37 and 21.02 g dm^{-3} combined with the Mombaça and Massai cultivars furnished the tallest plant heights, which were 94.19 and 72.81 cm, respectively (Fig. 2).

The results of the present study concur with findings of [17] who demonstrated that plant ash encouraged the height increase in the Marandu grass (*Brachiaria brizantha*). These authors reported that the vegetable ash could minimize the time in which the grasses achieved cutting height, with a notable increase and, therefore, could be a low-cost substitute in pasture management. Plant height is a crucial factor in pasture management, as it specifies the entry time of the animals into the pasture.

[5] in their study on the plant ash doses (0, 5, 10, 15 and 20 g dm^{-3}) in the Sudan grass, noted a significant spurt in the plant height as a response to the vegetable ash doses applied to the soil, with the maximum height being recorded at the dose of 17.02.

For the variable number of tillers, clear evidence was seen in terms of the interaction between the cultivars and vegetable ash doses applied. From the findings of the cultivars under the influence of the plant ash doses (Table 4), it was evident that at the plant ash dose of 8 g dm^{-3} the cultivar Massai showed a remarkably greater number of tillers when compared to that of the cultivar Mombaça.

The cultivar Mombaça showed no noteworthy difference in the number of tillers in response to the increased doses of the vegetable ash. This was attributed to its own morphological characteristic of not profiling in huge amounts. It must be highlighted that the tiller production is a very vital structural characteristic, acting as a critical indicator for forage grass growth.

Splitting the application of the vegetable ash doses within the cultivars strongly affected the plants, adjusting to the quadratic model of regression. The 25.79 g dm^{-3} and 25.78 g dm^{-3} doses for the cultivars Massai and Mombaça revealed a greater number of tillers, of 81.66 and 34.60, respectively (Fig. 3). It is evident that even when the differences in the characteristics between the two cultivars were taken into account the vegetable ash doses applied were identical to the point of achieving the maximum yield of tillers.

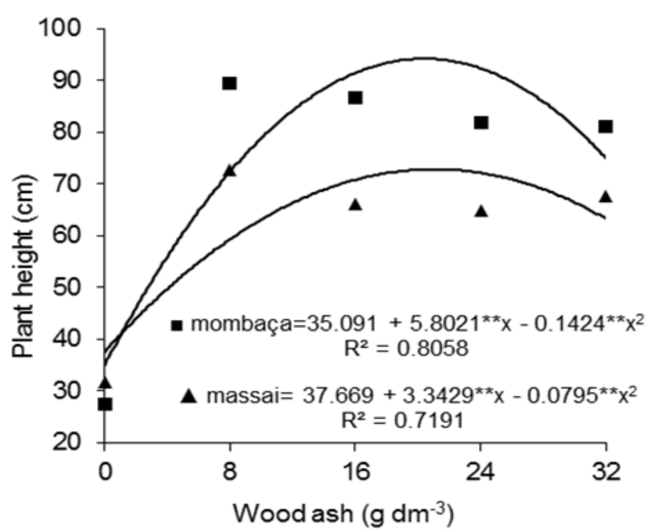

Fig. 2. The height of plants of Mombaça grass and Massai grass submitted to doses of wood ash in Oxisol.

*** significant at 1% probability*

Table 4. Number of tillers of Mombaça grass and Massai grass submitted to doses of wood ash in an oxisol

Cultivars	Number of tillers (plant^{-1})				
	Wood ash (g dm^{-3})				
	0	8	16	24	32
Massai	20.4 A	67.4 A	66.6 A	78.2 A	81.2 A
Mombaça	16.2 A	30.4 B	30.8 B	32.6 B	34.8 B

Means followed by the same letter do not differ in the column by the Tukey test up to 5% probability

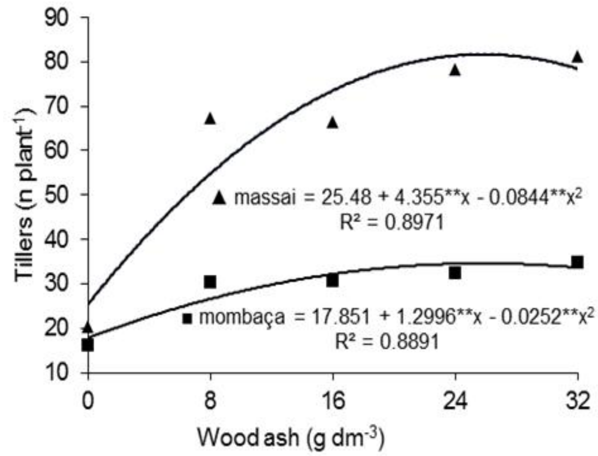

Fig. 3. Number of tillers of Mombaça grass and Massai grass submitted to doses of wood ash in an Oxisol.

*** significant at 1% probability*

In grasses, tillage is fundamental to growth, as it is responsible for the reproductive capacity post cutting and the perennial of foragers. Tilling is the variable that exerts the greatest effect on forage accumulation and is efficient when there is a speedy and abundant emission of leaves, which will, in turn, give rise to more numbers of potential buds, thus favoring the production of new tillers; however, it necessitates the implementation of effective management practices and appropriate environmental conditions [27].

Among the management practices, fertilization and cutting or grazing height influence tillering the most. Thus, fertilization utilizing vegetable ash plays a crucial role in the increased yield of new tillers in the Mombaça and Massai grasses, encouraging the rise in the production and vigor of these forage grasses.

One significant effect was noted on the chlorophyll index only for the vegetable ash doses applied. The plant ash affected the leaf chlorophyll index by adjusting for the quadratic regression model, in the assessment done at 35 DAE (Fig. 4), indicating that the 22.88 g dm^{-3} ash dose favored the highest chlorophyll index (48.04).

The SPAD reading is positively related to the chlorophyll content of the plant, influenced mostly by nutrient absorption, nitrogen in particular [28,29]. It is evident that the plant ash applied to the soil enhances the utilization of the applied nitrogen, which can be related to the potassium and magnesium being supplied by this residue, as a 3:1 nitrogen to potassium ratio is highly recommended [30]. Magnesium, the key component of the chlorophyll molecule, plays a vital part in the photosynthetic reactions [31,32,33].

[7] furnished similar results in their evaluation of the gray ash doses for the cotton plants, applied to the Oxisol. They reported a rise in the chlorophyll levels and ascribed this effect to the vegetable ash applied to the soil, which had resulted in the improved nitrogen absorption capacity. Studies using gray doses in the radish crop revealed a strong influence on the chlorophyll content due to the increased supply of nutrients which play a role in the chlorophyll synthesis and the photosynthetic process [8].

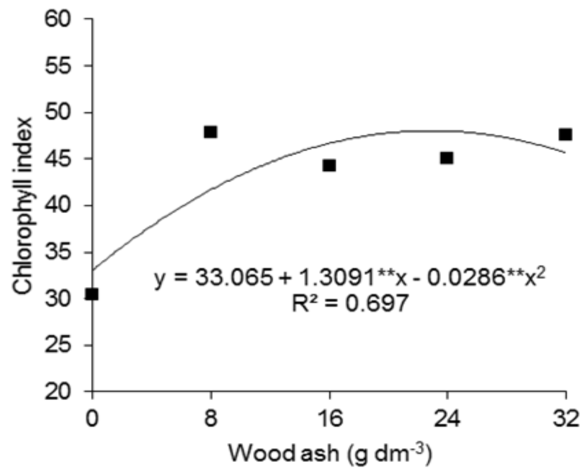

Fig. 4. Chlorophyll index (SPAD value) of forage grasses submitted to doses of wood ash in oxisol

*** significant at 1% probability*

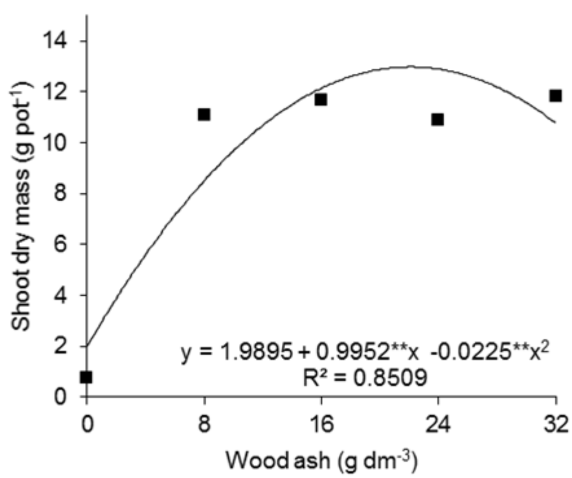

Fig. 5. Shoot dry mass of Mombaça grass and Massai grass submitted to doses of wood ash in Oxisol

*** significant at 1% probability*

While considering plant development and evaluating the yield of the dry mass of the aerial parts, a powerful but isolated effect was noted for the vegetable ash doses and the cultivars. This variable was observed, according to the vegetable ash doses to be adjusted to the quadratic model of regression, at 35 DAE (Fig. 5), at which time the 22.11 g dm^{-3} dose induced the highest yield of the dry mass of the aerial parts (12.99 g pot^{-1}).

The spurt in the dry mass of the aerial plant parts can be justified as arising as a response to the nutrients available in the vegetable ash, like potassium, phosphorus, calcium, magnesium and other micronutrients [34]. These nutrients facilitate nitrogen absorption and metabolism within the plant, consequently supporting the production of new tissues, increasing the leaf area index and longevity of the photosynthetically active leaves which, under appropriate conditions will raise their efficient utilization of solar radiation and consequently increase the accumulation of the dry matter [35].

An accurate application of the ash may boost the forage growth as the ash contains nutrients essential for the vital processes in the plant, including photosynthesis, respiration, and protein synthesis [36].

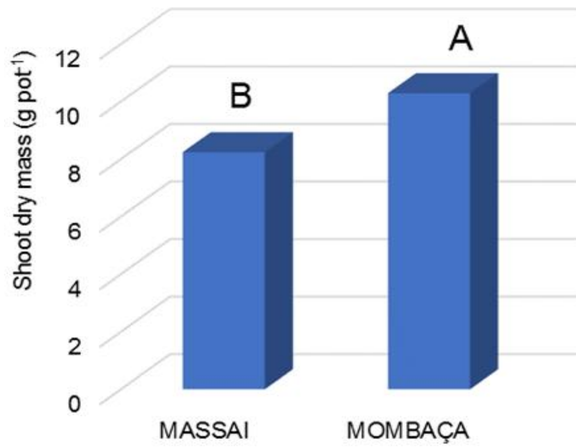

Fig. 6. Shoot dry mass of the cultivars Capim Mombaça and Massai cultivated in oxisol

[37] reported positive results for the increased yield in the dry mass of the shoot after the application of the vegetable ash in their work with Crotalaria juncea in response to the added vegetable ash doses in the Oxisol of the Cerrado. [38] reported a spurt in the dry mass of the aerial parts of the maize with the rise in the magnesium and calcium level provided via fertilization with wood ash.

On comparing the cultivars in light of the plant ash doses, the cultivar Mombaça revealed a higher dry matter yield (10.29 g pot $^{-1}$) than did the Massai grass (8.23 g pot^{-1}) (Fig. 6). These data are connected to those reported for the variable plant height, as the increase in the plant height naturally encourages a greater output of the aerial plant parts.

The results of the analysis of variance revealed a rise in the yield of the dry mass of the shoot for both forages, confirming that the management adopted by the plant ash favored the growth and yield of the Mombaça and Massai grasses.

4. CONCLUSION

1. Vegetable ash acts as a soil pH corrective and fertilizer, besides supplying the plants with nutrients.
2. The forage grasses show responses based on the vegetable ash doses acting as a fertilizer, based on the characteristics of each cultivar.
3. The vegetable ash doses between 20.37 and 25.78 g dm^{-3} produce the best results for the productive and structural traits of the Mombasa and Massai grasses.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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