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Short Communication

The Flammability of Shrubs and Trees in an *Acacia mangium* Plantation Based on Silica-free Ash Content

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Preliminary research to understand the flammability of 14 species of shrubs and 8 species of trees based on silica-free ash content was done in order to recognize which shrubs or trees are more flammable. The results show that the silica-free ash content of shrubs and trees leaves was greater than the stems ranging between 1.7% and 11.4% for leaf and 0.4% and 7.8% for the stems. The shrubs *Dicranopteris linearis, Imperata cylindrica, Eupatorium pubescens, Lantana camara, Eugenia* sp., *Cliforia laurifolia, Pterospermum* sp., *Hibiscus similis, Clidemia hirta* and *Trema orientalis* must be considered when fire invades the plantation as well as the tree *Paraserianthes falcataria, Eucalyptus urophylla, Callliandra callothyrsus,* and *Peronema canescens.*

Key words: *Acacia mangium*, flammability, fuel chemical, inorganic compound, silica-free ash

Previous research shows that one of the reasons why so much an *Acacia mangium* plantation was burned was the high level of fuel available in the vegetation as a result of poor maintenance (Saharjo, 1997b). In the case of *A. mangium*, fuel load increases until the second year and then decreases significantly as canopy gradually tend to close. In the second year, the flame temperature was highest, resulting in the most devastating destruction (Saharjo, 1997a). Fire may be defined as the interaction between fuel, energy, and environment. The type and magnitude of any fire that either develops into a destructive force or into a useful tool depends on the supply of fuel (Shafizadeh, 1968).

Communities with a readily available energy source would be characteristically highly flammable and would tend to have a frequent incidence of fire. The energy level sets the stage for potential flammability, but moisture-content regimes of plant communities determine fire seasons or burning peaks. The structure of plant communities is important in influencing the availability of energy and rate of energy release (Mutch, 1970).

The chemical composition of plants and fuels are an important influence in fire behavior (Mutch, 1970). Fire severity is related to the energy content (gross heat of combustion). However, the availability of energy for combustion can be inhibited by certain inorganic constituents (Broido and Nelson, 1964). These inorganic constituents are minerals found in the ash content of fuels (Broido and Nelson, 1964) and specifically in the acid-insoluble ash (silica-free ash) content (Mutch, 1970). These inorganic compounds produce a catalytic effect that inhibits the formation of combustible compounds during pyrolisis. Pyrolisis is the thermal degradation of plant molecules prior to combustion. The pyrolysis of plant materials produces the volatiles that support flaming combustion. Increasing the acid-insoluble ash (silica-free ash) content minimizes or decreases the net pyrolityc reactions leading to flaming combustion (Broido and Nelson, 1964).

Our research objective, therefore was to recognize which shrubs or trees are more flammable based on silica-free ash content in an *A. mangium* plantation, in order to prevent fire invasion.

Materials and Methods

Three samples of green leaves and stems from 14 dominant shrubs: *Dicranopteris linearis, Imperata cylindrica, Lantana camara, Eupatorium pubescens, Melastoma malabathricum, Trema orientalis, Hibiscus similis, Clidemia hirta, Cajanus cajan, Rubus moluccanus, Stachytarfheta indica, Eugenia* sp., *Pterospermum* sp., and *Cliforia laurifolia* and tree species : *Schima wallichii, Vitex pubescens, Gmelina arborea, Peronema canescens, Eucalyptus urophylla, A. mangium, Paraserianthes falcataria,* and *Calliandra callothyrsus* in an *A. mangium* plantation were analyzed for the total ash, silica content and silica-free ash. These samples were taken from one industrial forest plantation that was located in South Sumatra, Indonesia, in the period from August to September 1996.

Total ash is determined by complete combustion of a 2 g sample in a muffle furnace at 573 ℃ for 3 h. Acid-insoluble (silica-free ash) is determined by boiling the total ash sample in 5 ml of 6 M HCl (Keulen and Young, 1977) and re-ashing. The acid-insoluble ash (silica-free ash) component is the amount that remains after boiling and re-ashing (Kaufmann *et al.*, 1988).

This analysis was done in the wood chemical laboratory at the Faculty of Forestry, Bogor Agricultural University, Indonesia.

A completely random design of variance was used to test for differences among shrubs and trees at the leaf and stem parts. To detect significant differences among silica-free ash content ($p \leq 0.05$), the Duncan test (Steel and Torrie, 1981) was applied.

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Table 1 Silica-free ash and total ash content of shrubs and trees for leaves.

No.	Fuel species	Silica-free ash (%)	Total ash (%)
1.	*Dicranopteris linearis*	(1.7 ± 0.2)[a]	(6.0 ± 0.1)
2.	*Imperata cylindrica*	(2.2 ± 0.2)[a]	(6.2 ± 0.2)
3.	***Paraserianthes falcataria***	(3.4 ± 0.2)[b]	(3.7 ± 0.1)
4.	*Cliforia laurifolia*	(3.4 ± 0.1)[b]	(4.3 ± 0.1)
5.	*Hibiscus similis*	(3.5 ± 0.1)[bc]	(6.83 ± 0.02)
6.	*Cajanus cajan*	(4.121 ± 0.003)[bcd]	(6.842 ± 0.004)
7.	***Acacia mangium***	(4.1 ± 0.1)[bcd]	(4.3 ± 0.1)
8.	*Eupatorium pubescens*	(4.3 ± 0.3)[cd]	(5.7 ± 0.2)
9.	*Eugenia* sp.	(4.6 ± 0.1)[de]	(5.001 ± 0.004)
10.	***Vitex pubescens***	(4.7 ± 1.2)[de]	(7.9 ± 1.4)
11.	***Eucalyptus urophylla***	(4.7 ± 0.1)[de]	(8.7 ± 0.1)
12.	*Trema orientalis*	(4.9 ± 0.1)[de]	(10.9 ± 0.4)
13.	***Peronema canescens***	(5.1 ± 0.1)[e]	(9.5 ± 0.2)
14.	*Rubus moluccanus*	(5.2 ± 0.4)[e]	(6.45 ± 0.5)
15.	***Calliandra callothyrsus***	(5.2 ± 0.1)[e]	(7.1 ± 0.1)
16.	*Pterospermum* sp.	(6.0 ± 0.1)[f]	(7.6 ± 0.1)
17.	*Lantana camara*	(6.666 ± 0.003)[f]	(7.3 ± 0.1)
18.	*Stachytarfheta indica*	(7.4 ± 0.3)[g]	(15.4 ± 0.4)
19.	***Gmelina arborea***	(7.5 ± 0.1)[g]	(8.9 ± 0.1)
20.	*Clidemia hirta*	(7.8 ± 0.5)[g]	(8.2 ± 0.6)
21.	*Melastoma malabathricum*	(10.8 ± 0.3)[h]	(12.0 ± 0.4)
22.	***Schima wallichii***	(11.4 ± 0.1)[h]	(13.1 ± 0.1)

* Fuel species with ***bold*** type are trees. ** Means are significantly different when standard error is followed by different letters ($p \leq 0.05$).

Table 2 Silica-free ash and total ash content of shrubs and trees for stems.

No.	Fuel species	Silica-free ash (%)	Total ash (%)
1.	*Dicranopteris linearis*	(0.4 ± 0.1)[a]	(1.0 ± 0.1)
2.	***Paraserianthes falcataria***	(1.4 ± 0.0)[b]	(1.8 ± 0.1)
3.	***Eucalyptus urophylla***	(1.6 ± 0.1)[c]	(1.70 ± 0.05)
4.	***Calliandra callothyrsus***	(1.8 ± 0.2)[c]	(2.0 ± 0.2)
5.	***Peronema canescens***	(1.9 ± 0.1)[c]	(2.2 ± 0.1)
6.	*Eupatorium pubescens*	(2.2 ± 0.2)[d]	(2.9 ± 0.6)
7.	*Lantana camara*	(3.0 ± 0.1)[e]	(3.3 ± 0.3)
8.	*Eugenia* sp.	(3.2 ± 0.1)[ef]	(3.2 ± 0.1)
9.	*Cliforia laurifolia*	(3.3 ± 0.3)[fg]	(3.5 ± 0.3)
10.	*Pterospermum* sp.	(3.3 ± 0.6)[fg]	(3.5 ± 0.5)
11.	*Hibiscus similis*	(3.4 ± 0.3)[g]	(3.4 ± 0.3)
12.	***Vitex pubescens***	(3.4 ± 0.2)[g]	(3.6 ± 0.2)
13.	***Acacia mangium***	(3.4 ± 0.3)[g]	(3.60 ± 0.04)
14.	*Clidemia hirta*	(3.8 ± 0.1)[h]	(4.1 ± 0.2)
15.	*Rubus moluccanus*	(3.8 ± 0.1)[h]	(4.10 ± 0.04)
16.	*Trema orientalis*	(5.3 ± 0.5)[i]	(6.6 ± 0.1)
17.	***Gmelina arborea***	(5.7 ± 0.3)[j]	(6.0 ± 0.3)
18.	*Melastoma malabathricum*	(6.3 ± 0.8)[k]	(6.4 ± 0.8)
19.	***Schima wallichii***	(7.8 ± 0.9)[l]	(7.9 ± 0.9)

* Fuel species with ***bold*** type are trees. ** Means are significantly different when standard error is followed by different letters ($p \leq 0.05$).

Results and Discussion

Table 1 shows that silica-free ash of shrubs for leaves ranges between 1.7% and 10.8%, and at the tree stages between 3.4% and 11.4%. The most flammable leaves of shrubs had the lowest silica-free ash; *D. linearis* with 1.7% and *I. cylindrica* with 2.2%. At the tree stage, *P. falcataria* had a content of 3.4%. The highest silica-free ash of shrubs for leaves was *M. malabthricum* with 10.8% and at the tree stage, *S. wallichii* with 11.4%.

Total ash content of shrubs for leaves was between 4.3% in *C. laurifolia* and 15.4% in *S. indica*. In trees, total ash content was between 3.7% in *P. falcataria* and 8.9% at *S. wallichii*.

Table 2 shows that silica-free ash content of shrubs for stems was between 0.4% and 6.3%, and for tree it was between 1.4% and 7.8%. The lowest silica-free ash content of shrubs for stems was for *D. linearis* with 0.4% and the highest was *M. malabathricum* with 6.3%. At the tree stages, the lowest silica-free ash content for stems was *P. falcataria* with 1.4% and the highest was *S. wallichii* with 7.8%.

Total ash content of shrubs for stems was between 1.0% in *D. linearis* and 6.4% in *M. malabathricum*. For trees, total ash content for stems was 1.8% in *P. falcataria* and 7.9% in *S. wallichii*. The total ash content of shrubs and trees for stems can be said to be between 1.0% to 7.9%.

It seems that the silica-free ash content for stems of shrubs and trees was lower than for leaves. Silica-free ash content of shrubs and trees for stems was between 0.4% and 7.8%, while for leaves it was between 1.7% and 11.4%. These results are quite similar to the data of Philpot (1970), where silica-free ash content for leaves was higher than for stems.

At shrub stage, *D. linearis* stems will burn first when fire invades the plantation because it has the lowest silica-free ash. It then continues to *I. cylindrica* leaves, *E. pubescens* stems, *L. camara* stems, *Eugenia* sp. stems and *C. laurifolia* stems. It was suspected also that the last shrub that would be attacked was *M. malabathricum* because it has the highest silica-free ash content. At the tree stage, *P. falcataria* will be the most devastated by fire invades, as happened in 1994 in this research site (Saharjo, 1999). One of the reasons for this was because of the high fuel load stored in the plantation, dominated by *I. cylindrica* and also caused by the leaves and branches of *P. falcataria* with the lowest silica-free ash. The next trees that would be attacked are *E. urophylla*, *C. callothyrsus*, and *P. canescens*.

Based on the silica-free ash content, shrubs that should be considered when fire invades the plantation are: *D. linearis* (stems), *I. cylindrica* (leaves), *E. pubescens* (stems), *L. camara* (stems), *Eugenia* sp. (stems), *C. laurifolia* (stems), *Pterospermum* sp. (stems), *H. similis* (leaves), *C. hirta* (stems), and *T. orientalis* (leaves and stems). At the trees stage: *P. falcataria*, *E. urophylla*, *C. callothyrsus*, and *P. canescens*.

Conclusion

Silica-free ash can be used as an indicator to recognize which part of the shrubs or trees are more flammable. Leaves are higher than stems, and the content were between 1.7% and 11.4% for leaves, and between 0.4% and 7.8% for the stems.

Based on the silica-free ash content, shrubs that should be taken into attention in order to prevent fire invasion area: *D. linearis* (stems), *I. cylindrica* (leaves), *E. pubescens* (stems), *C. laurifolia* (stems), *Pterospermum* sp. (stems), *H. similis* (leaves), *C. hirta* (stems), and *T. orientalis* (leaves and stems). Trees easily attacked by fire are: *P. falcataria*, *E. urophylla*, *C.*

callothyrsus, and *P. canescens.*

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