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Decomposition dynamics of leaves of six indigenous fruit trees commonly found on croplands of southern Africa

J.B. Nduwayezu* and W. Mojeremane
Department of Crop Science and Production, Botswana College of Agriculture, Private Bag 0027 Gaborone,

ABSTRACT

Leaf litter decomposition plays a crucial role in the cycling of both nutrients and energy in the tropical croplands. A field experiment was conducted at Botswana College of Agriculture's Research Farm in 2003 to compare the leaf material decomposition rates among six native tree species: *Azanza garckeana, Berchemia discolor, Sclerocarya birrea, Strychnos cocculoides, Vangueria infausta* and *Strychnos pungens*. The litterbags (20 cm x 25 cm x 2 mm) containing leaves of each species were incubated under field conditions and retrieved after 2, 4, 6, 8, 10 and 12 weeks..During the first 6-8 weeks of incubation, the leaf dry weight loss of *Vangueria infausta* increased by 36.8% while that of *Azanza garckeana* increased by 85.4%. At the end of incubation period, both *Vangueria infausta* and *Azanza garckeana* showed the highest leaf dry weight losses (96.2 and 95.0% respectively) as compared with *Berchemia discolor* (79.3%), *Sclerocarya birrea* (78.7%), *Strychnos pungens* (72.3%) and *Strychnos cocculoides* (71.3%). It is concluded that *Vangueria infausta* and *Azanza garckeana* have high agroforestry potential as sources of organic manure and that application of their foliages can improve both soil fertility and crop productivity. Proper timing of foliages application is important if nutrients released from these sources are to be synchronized with specific agricultural crops demand.

Keywords: Agroforestry, foliage decomposition, synchronization, indigenous trees/shrubs, Africa

INTRODUCTION

Food shortages and increasing environmental degradation around villages and settlements are mainly caused by low soil fertility and moisture deficiency. These are serious inter-linked problems facing the people living in rural areas of Botswana and other countries in the region. To overcome these problems, some of the agroforestry practices, especially incorporating trees into the existing local farming systems and biomass transfer technology seem to be viable option as compared with the use of expensive chemical fertilizers and abundant but high labour-demanding animal manures (Nduwayezu, 2001). The choice of appropriate agroforestry species for desirable organic nutrients reserves, however, is very crucial if the technology is to be adopted by the targeted resource-poor farmers in rural areas in Africa.

In their efforts to improve food supply, generate income and conserve their environment, the subsistence smallholders in Botswana retain in their fields a diversity of trees, especially indigenous fruit trees and other plants of socio-economic importance. Some of the tree species preferred by the farmers include *Sclerocarya birrea subsp. Caffra* (*Anacardiaceae*), *Vangueria infausta* (*Rubiaceae*), *Azanza garckeana* (*Malvaceae*), *Strychnos cocculoides* (*Loganiaceae*), *Berchemia discolor* (*Rhamnaceae*), *Strychnos pungens* (*Loganiaceae*) and *Adansonia digitata*

(Bombacaceae) (Mateke and Tshikae. 2002; Mojeremane and Tshwenyane. 2004).

Some of the trees retained in croplands by rural farmers in Africa repeatedly take up nutrients from the soil and return them by decomposition of litter (Young, 1997; Guo and Sims, 1999). The rate of nutrients released and their availability for agricultural crops uptake is generally governed by the decomposition rates of the fallen litter (Guo and Sims, 1999) or applied leaf materials (Giller, 2000; Mafongoya *et al.*, 2000; Nduwayezu, 2001). The addition of tree leaves and branches as mulches to soils has been shown to improve site micro-environmental conditions (Budelman, 1989), soil physical, chemical and biological properties (Nduwayezu, 2001) and increase agricultural crops productivity (Onim *et al.*, 1990; Montagnini *et al.*, 1993). Although some indigenous tree species have high agroforestry potential (Nduwayezu, 2001) there is evidence that most of the research on indigenous fruit trees focussed on domestication, mycorrhizae formation potential and fruit nutritional qualities (Mateke and Tshikae, 2002). Information on nodulation potential, leaf litter quality attributes/fertilizer value and decomposition rate of tree foliage is completely lacking in Botswana.

This study, therefore, was designed to determine the agroforestry potential of *Vangueria infausta, Azanza garckeana, Berchemia discolor, Sclerocarya birrea subsp. caffra, Strychnos pungens* and *Strycnos cocculoides*. Also, the objective was to determine the leaf decomposition rates of the selected indigenous fruit tree species.

MATERIALS AND METHODS

The study was conducted at the Botswana College of Agriculture, Notwane Research Farm (Latitude: 24° 34'S; Longitude: 25°54' E; altitude: 994 m) located at Sebele, which is approximately 10 km north of Gaborone along the north to south highway. Sebele is characterized by a semi-arid climate with a mean annual rainfall of 538 mm. Most of the rain falls in the summer starting from late October and continues to March/April. The study area is characterized by shallow sandy loam soils and Acacia woodland.

The leaves of *Vangueria infausta, Azanza garckeana, Berchemia discolor, Sclerocarya birrea, Strychnos pungens* and *Strycnos cocculoides* were collected from mature healthy trees retained in the Butare (Francistown) and Sebele (Gaborone) local farms in September 2003. They were then air-dried and stored in a safe and insect-free place.

According to Wyk and Wyk (1997) and Mbuya *et al.* (1994) *Vangueria infausta* is a deciduous hairy shrub or shapeless tree to 8 m, with a short trunk, pale grey-brown bark peeling in untidy flakes, hanging hairy branchlets and dull green broadly oval leaves having velvety hairy surfaces. The species is widely distributed in wooded grassland, often rocky or sandy places at low to fairly high altitudes south to Malawi and South Africa. *Azanza garckeana* on the other hand, is a deciduous tree 3-8 m with rounded crown, brown rough bark, branchlets having woolly hairs and simple, alternate leaves having 3-5 lobes, rough hairs above and soft hairs below. This is the only Azanza species found in Africa from the Sudan to Southern Africa. It is common from low to higher altitudes as a scattered tree in several types of woodland and on termite mounds all over Tanzania. *Berchemia discolor* is a semi-deciduous shrub or tall tree to 18 m with erect spreading branches making a heavy rounded crown, grey-black, cracking and scaly bark, corky spots on young greenish branches and simple, alternates, shiny dark green and oval leaves which are sticky when young. This species is widespread from the Sudan to South Africa and grows in semi-desert grassland, open woodland or at lower altitudes and along river valleys, especially on termite mounds. *Sclerocarya birrea* is a medium to large deciduous tree (10-18 m) with an erect trunk and spreading, rounded crown.

The leaves are compound and crowded at tips of branches. This is an African fruit tree occurring from Ethiopia south to Natal at medium to low altitudes (100-1600 m) scattered in mixed deciduous woodland and wooded grassland. *Strychnos cocculoides* is an armed semi-deciduous shrub or small tree (3-8 m high) with a compact, rounded crown, thick, ridged and corky brown bark and with broadly ovate-oblong to almost circular leaves with or without rough hairs, shiny above, dull below, 5 veins from the base. This spiny shrub, which grows naturally in Brachystegia and deciduous woodlands, especially on sandy soils or rocky hills is found throughout the drier parts of central and southern Africa. *Strychnos pungens* is a small deciduous to evergreen tree with thick and fissured bark, thick, rough and corky branchlets having swollen nodes and conspicuous lenticels. The leaves are usually elliptic, hard and rigid, hairless with 3-5 veins from the base and apex ending in hard, sharp spine. The species occur in bushveld often on rocky places.

This experiment was carried out in September 2003 and was arranged in a Randomized Completely Block Design with 6 treatments and 3 replications. The treatments included in this study were *Azanza garckeana, Berchemia discolor, Sclerocarya birrea, Strycnos cocculoides, Strychnos pungen and Vangueria infausta.* After land preparation using a tractor, a systematic point location method was used to locate the six positions of litterbags along diagonals and medians of each treatment plot (Nduwayezu, 2001). Two weeks before establishing the experiment, square holes (30 cm x 30 cm x 20 cm) for placing litter bags were dug using a pick and a shovel. Ten grams of dry leaf material of each species were placed in the 20 cm x 25 cm x 2 mm litterbags.

The litter bags with the open end being tied with a nylon string were then buried in the top soil horizon of each plot (3 m x 3 m) in each block and left to incubate at field conditions for 2, 4, 6, 8, 10 and 12 weeks respectively. The locations of the six litterbags of each treatment were marked using wooden sticks.

The observation was taken after 2, 4, 6, 8, 10 and 12 weeks. At each sampling period, one litterbag of each treatment from each replication was randomly retrieved, carefully brushed and made free from weeds and other foreign material by hand. The residual materials were oven dried to constant weight at 70\C and left to cool before recording the final weight. The leaf dry weight loss percentage for each species was calculated as described by Guo and Sims (1999).

Data were subjected to the analysis of variance and significant treatment means were compared using the Duncan's Multiple Range Test (DMRT) of MSTAT-C.

RESULTS

The foliages of all the species decomposed considerably fast during the first 6-8 weeks of incubation (Table 1). The leaf dry weight loss of *Vangueria infausta* increased by 36.8% (from 65.8 to 90.0 %) while that of *Azanza garckeana* increased by 85.4% (from 47.1 to 87.3%). Only the leaf materials of *Strychnos pungens* showed the dry weight loss of less than 50 % after 8 weeks of incubation as compared with other species. During the last stage of decomposition (10-12 weeks), *Strychnos pungens* and *Strychnos cocculoides* showed the highest increase in leaf dry weight losses (increase by 14 and 7.5 % respectively) as compared with other species. At the end of incubation period (12 weeks), however, both *Vangueria infausta* and *Azanza garckeana* showed higher leaf dry weight losses (96.2 and 95.0%) than *Berchemia discolor* (79.3%), *Sclerocarya birrea* (78.7%), *Strychnos pungens* (72.3%) and *Strycnos cocculoides* (71.3%).

Table 1: Leaf dry weight loss of various indigenous fruit trees at different intervals of field incubation at Notwane Farm, Gaborone, Botswana.

Species	Average leaf dry weight loss (%) of various species					
	Incubation period (weeks)					
	2	4	6	8	10	12
Azanza garckeana	8.1 a	31.6 a	47.1 b	87.3 a	91.2 a	95.0 a
Berchemia discolor	6.2 c	8.6 bc	28.3 c	64.6 b	76.6 b	79.3 b
Sclerocarya birrea	7.7 ab	8.3 bc	39.3 bc	56.7 bc	75.6 b	78.7 b
Strychnos cocculoides	6.4 bc	12.9 b	32.7 bc	51.7 c	66.3 c	71.3 c
Strychnos pungens	4.3 d	5.0 c	25.7 c	47.0 c	63.5 c	72.3 bc
Vangueria infausta	8.6 a	35.8 a	65.8 a	90.0 a	92.7 a	96.2 a

Means in the same column that are followed by the same letter do not differ significantly ($P \leq 0.05$) (DMRT)

DISCUSSION

The observed fast decomposition rates of *Vangueria infausta* and *Azanza garckeana* foliages during the 6-8 weeks of incubation can probably be attributed to the increased microbial activity and the observed termites which is in agreement with reports by some researchers suggesting that addition to the soil of high quality green manures enhanced soil microbial activity (Tisdale *et al.*, 1990; Sakala *et al.*, 2000). A positive influence of termites and other macrofauna on decaying organic materials was also reported in studies with *Gliricidia sepium* leaves (Zaharah and Bah, 1999). Based on the earlier reported resemblance between decomposition rate and N release (Nduwayezu, 2001) attributable to the close linkage between C and N in the protein molecule (Thompson and Troeh, 1979; McGill *et al.*, 1981; Cheng and Wen, 1998), it can be noted that the observed fast decomposition rate of *Vangueria* and *Azanza* leaves during the 6-8 weeks period probably coincided with the grand period of high nutrients, especially N release from these sources (Martius *et al.* 1999; Sakala *et al.*, 2000). This implies that *Vangueria* and *Azanza* manures should be incorporated into the soil before maize crop sowing in order to improve nutrients use efficiency by the plant, which is in line with studies in Tanzania on Senna-maize crop interaction (Nduwayezu, 2001).

Since the amount of nutrients, especially N, available for agricultural crops uptake depends on the quantity and quality of organic materials added to the soil, the chemical characteristics (e.g. initial N concentration, carbon-pools, lignins and soluble polyphenols) (Tisdale *et al.*, 1990; Handayanto *et al.*, 1997; Seneviratne *et al.*, 1998; Giller, 2000; Nduwayezu, 2001) of the leaf materials from indigenous trees and shrubs including fruit trees commonly found on croplands in Africa need to be determined if nutrients released from these sources are to be synchronized with agricultural crops demand. In addition to the litter quality attributes of these indigenous plants, the knowledge of other factors controlling the decomposition rate of organic materials added to the soil (e.g. plant age, conditions, methods and lengths of litter incubation, climate and soil characteristics (Oglesby and Fownes, 1992; Anthofer *et al.*, 1998, Mafongoya *et al.*, 1996; Cheng and Wen, 1998) is also very crucial when choosing the type and time of organic manures application (Handayanto *et al.*, 1994).

The slow decomposition rates of *Strychnos pungens* and *Strycnos cocculoides* leaf materials as evidenced by their failure to reach the half-life during the first 8 weeks of incubation and the high increases in leaf dry weight losses during the last period of incubation suggest that these organic materials are suitable for very slow-growing agricultural crops, minimizing soil water losses and improving other soil properties (Budelman, 1989)

CONCLUSIONS AND RECOMMENDATIONS

Vangueria infausta and *Azanza garckeana* are indigenous fruit tree species with high agroforestry potential. The leaves of these trees were found to decompose fast within the first eight weeks of field incubation. Application of sufficient green manures from these organic materials, however, needs to be properly timed in order to synchronize nutrients release from these sources with crop demand.

More research, however, is needed to determine the leaf litter quality attributes of indigenous trees, which are commonly used, by the subsistence farmers in Southern Africa and patterns of nutrients release from these organic reserves. Mixing the fast-decomposing foliages of *Vangueria infausta* and *Azanza garckeana* with slow-decomposing leaves of *Strychnos* species may improve nutrients availability for uptake by slow-growing agricultural crops. The critical periods of high nutrients demand by agricultural crops commonly grown in dry lands of Botswana and other Southern African countries needs to be determined to ensure efficient use of tree foliages.

More studies are also needed to determine the appropriate litter placement methods and litterbag sizes optimizing both soil microbial and macro-organisms' activity during the process of organic materials decomposition

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