

Aboveground biomass production of different species of shrub and gramineae on two contrasting soil in Eastern Democratic Republic of Congo

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ABSTRACT: Fallow is one of the methods used to restore soils fertility and to produce fodder for domestic animals. The objective of this study was to compare the biomass yields of different species of shrubs and grasses in contrasting soils in South Kivu Province in the Eastern of Democratic Republic of Congo. The experimental design was a randomized block containing four repetitions. Each repetition contained four plots corresponding to four species of gramineas (*Pennisetum purpureum*, *Setaria sphacelata*, *Brachiaria ruziziensis* and *Tripsacum laxnum*) or shrubs (*Albizia chinensis*, *Leucaena diversifolia*, *Calliandra calothyrsus* and *Leucaena leucocephala*). Highly significant differences ($P = 0.001$) were observed between species and between sites for all observed parameters. The quantities of biomass produced by the *Pennisetum* in the two sites (29.31 t/ha) were significantly higher than those produced by the 3 others species followed by *Setaria* (19.54 t/ha), *Brachiaria* (13.84 t/ha) and *Tripsacum* (13.8 t/ha). The same trend was observed for shrubs species, the quantities of biomass produced by the *Calliandra* in the two sites (11 t/ha) were significantly higher ($P = 0.001$) than those produced by the 3 others species followed by *Leucaena diversifolia* (8 t/ha), *Leucaena leucocephala* (3 t/ha) and *Albizia chinensis* (2 t/ha). Concerning the sites, a highest significant difference was observed between the two sites, the biomass yields produced at Mulungu (7.3 and 23.7 t/ha) were significantly higher than those for Mushinga (4.7 and 14.5 t/ha), for shrubs and gramineas respectively. For forage biomass production and soil productivity restoration, the combination of *Calliandra* and *Leucaena diversifolia*, and pennisetum-setaria can be used as improved fallow in the conditions of the trial sites. There is a need for follow-up research on soil production restoration to include these four species in trial at both sites in South Kivu Province.

KEYWORDS: Biomass, Forage, Improved fallow, Soil degradation, Yield.

1 INTRODUCTION

Soil fertility degradation on smallholder is the principal causes of declining food production in Africa including the East of Democratic Republic of Congo (DR Congo) [1]. This has the consequences of reducing farmers' incomes and increasing poverty in rural areas.

The use of fallow is one of the main methods used to restore soils productivity. However, Traditional fallows take several years (10 to 15 years) [2] and natural vegetation is slow to restore soil productivity. In contrast, leguminous shrubs and fast-growing grasses are planted to improve soil fertility in a short time [3].

The improved fallow is a natural fallow in which one or more species of grasses or shrubs fixing nitrogen or not, are introduced in order to accelerate the restoration of soil fertility, erosion control and / or to obtain various products such as fodder and wood as well as plant pest control [3], [4]. The species used are characterized by their rapid growth, their ability to produce a great quantity of biomass (leaves and wood), their deep root system and their great adaptation to local soil and climate conditions [6].

Calliandra calothyrsus, *Leucaena sp* and *Albizia chinensis* are among the main leguminous shrub species selected for soil fertility improvement in several countries including Kenya, DR Congo and Burundi [7], [8], [9], [10].

Calliandra calothyrsus is a nitrogen-fixing shrub. It is used to restore soil fertility. The tree also provides a good firewood, which dries well and burns rapidly [11]. The pruning's of *Calliandra calothyrsus* are used to feed cows, rabbits and other livestock in many parts of the world [8].

Calliandra calothyrsus is a riverine colonist with relatively rapid early growth. It is outcompeted in later successional stages but may often invade areas of continual disturbance such as roadsides or shifting cultivations. In its native Central American habitat, it grows at altitudes from sea level to 1,860 m in areas where the annual precipitation ranges from 700 to 3,000 mm. The plant is not very drought tolerant although it is able to withstand dry periods. In humid climates, the tree is evergreen, whereas in areas with a long dry season it is semi-deciduous. Under severe drought conditions, the tree will die back but will generally recover after the onset of the rainy season.

Calliandra calothyrsus grows well on a wide range of soil types ranging from deep volcanic loams to more acidic metamorphic sandy clays. It appears naturally well suited to the light textured slightly acidic soils of volcanic origin which are common to the humid and subhumid tropics of southeast Asia. The precipitation pattern in these areas shows a well defined wet and dry season and an annual rainfall of 2,000-4,000 mm. The plant is not tolerant of low oxygen tensions in waterlogged situations and does not grow well on poorly drained calcareous soils. Within its native environment, *C. calothyrsus* occupies areas with mean monthly maximum temperatures between 24 and 28°C and mean minimum temperatures of 18-24°C. These areas are frost-free but *C. calothyrsus* appears to have some cool tolerance.

Calliandra calothyrsus Meissn. (*Calliandra*) is a small, thornless leguminous tree native to Central America and Mexico. It has been introduced to many tropical regions where it is used in agroforestry systems for fuel wood, plantation. It is planted in many countries for reforestation of eroded, poor quality land around villages.

Leucaena diversifolia is an erect tree or shrub. It is a tropical upland species present in cool and seasonally wet areas. It is often grown in degraded and deforested areas dominated by *Imperata cylindrica* and *Themeda triandra*. It also serves as fodder for livestock. Firewood and charcoal are one of the main uses of this species [12].

In addition, some grass species such as *pennisetum*, *setaria*, *tripsacum* and *Brachiaria* are recommended for restoring soil fertility in short-term fallows in Africa [10], [14].

Pennisetum purpureum is used for a number of purposes except for forage use. Indeed, this plant is known for its capacity to protect soil against erosion and, it is cultivated at the edge of contour lines and food crops to limit soil loss. It produces a large amount of dry matter which, by decaying, improves the soil structure [6], [15], [16]. This material is made both in the soil (roots) and in the above ground (stems, leaves), the abundant roots break the clods and promote the passage of water [10].

Setaria sphacelata was developed for grazing and hay production. It is an aggressive perennial herb of arid tropical regions in the world. It prefers very hot climate and is limited to these tropical environments. It is drought resistant and is better suited to shallow soils and low rainfall, it is also used in restoring the fertility of degraded soils [17], [18], [19].

Tripsacum laxnum is a perennial forage, it is particularly useful as a green food during dry periods. Used as a hedge or for contour strips with or without legume on the hills to restore the fertility of degraded soils [18], [19]. It is used for the control of soil erosion.

Brachiaria ruziziensis is a herbaceous grass, semi-erect to creeping, native to Central Africa (Burundi, Rwanda, and the Ruzizi plain in the Democratic Republic of Congo (DR Congo.)) *Brachiaria* is able to remobilize rapidly from fertility to crops. In particular on highly saturated and more or less degraded acidic ferralitic soils, it produces the most biomass (aerial and root), making it a prime forage and soil fertility regenerator for sowing in annual successions and agriculture-livestock integration [21].

These species of shrubs and grass are regularly cut and the leaves buried or spread on the ground as mulching to fertilize soil. However, the production of biomass by the different shrubs and grass species depends on several factors among which, the soil characteristic and the characteristics of each species [16]. For example, when acid and exchangeable Al content are high in the soil, and the availability of exchangeable Ca, Mg and P is low, the biomass yield of *Pennisetum purpureum*, *Leucaena leucocephala* and several other species is weak [15].

In addition, biomass production by these different species can be affected by the agro-ecological and soil characteristics of different production sites. For example, the results of observations made by [9] on the production of fodder biomass by several shrub species in the South Kivu province of Eastern DR Congo showed that Calliandra produced more fodder biomass than the other species in the different experimental sites.

It is within this framework that the present work has set the objective of comparing the above ground biomass yields of different species of shrubs and grasses on two sites with contrasting soils in South Kivu in eastern DR Congo.

2 SITE, MATERIAL AND METHODS

2.1 SITES DESCRIPTION

The trial was established in two sites located in 2 territories in the South and North of South Kivu Province in Eastern DR Congo for one year, from January 2015 to January 2016. The Territory of Kabare, at the Research Center of INERA / Mulungu (02 ° 19'907 " South Latitude, 028 ° 46' 540' 'East Longitude, located at 1825 m altitude), in the "Territory of Walungu", "Groupement" of Mushinga (02 ° 45'592 " S, 028 ° 39 '591' 'East, located at 1592 m altitude).

The climate of the trial area has nine months of rain and three months of dry season, it is a humid tropical climate. The average annual temperature of this area varies between 16 and 20° C. The rainfall regime is bimodal, the first season (A) spreading from September to November and the second (B) from March to May. The average annual rainfall is 1572 mm [18]. Table one summarizes the soil characteristics of experimental sites.

Table 1. Soil characteristics of experimental sites

Sites	pH (Water)	Carbon (%)	N (%)	Phosphore (mg p/kg)	Al +++	Ca	K	Clay (%)	Sand (%)	Limon (%)
Mulungu	5.38a#	2.38b	0.27b	23.18a	0.69b	3.47a	0.45a	68.54a	15.92b	16.37a
Mushinga	4.32b	4.11a	0.43a	12.12b	4.43a	0.30b	0.08b	41.88b	40.95a	10.62b

#:Means in a column followed by the same letter are not significantly different from each other according to the HSD test at p value 0.05.

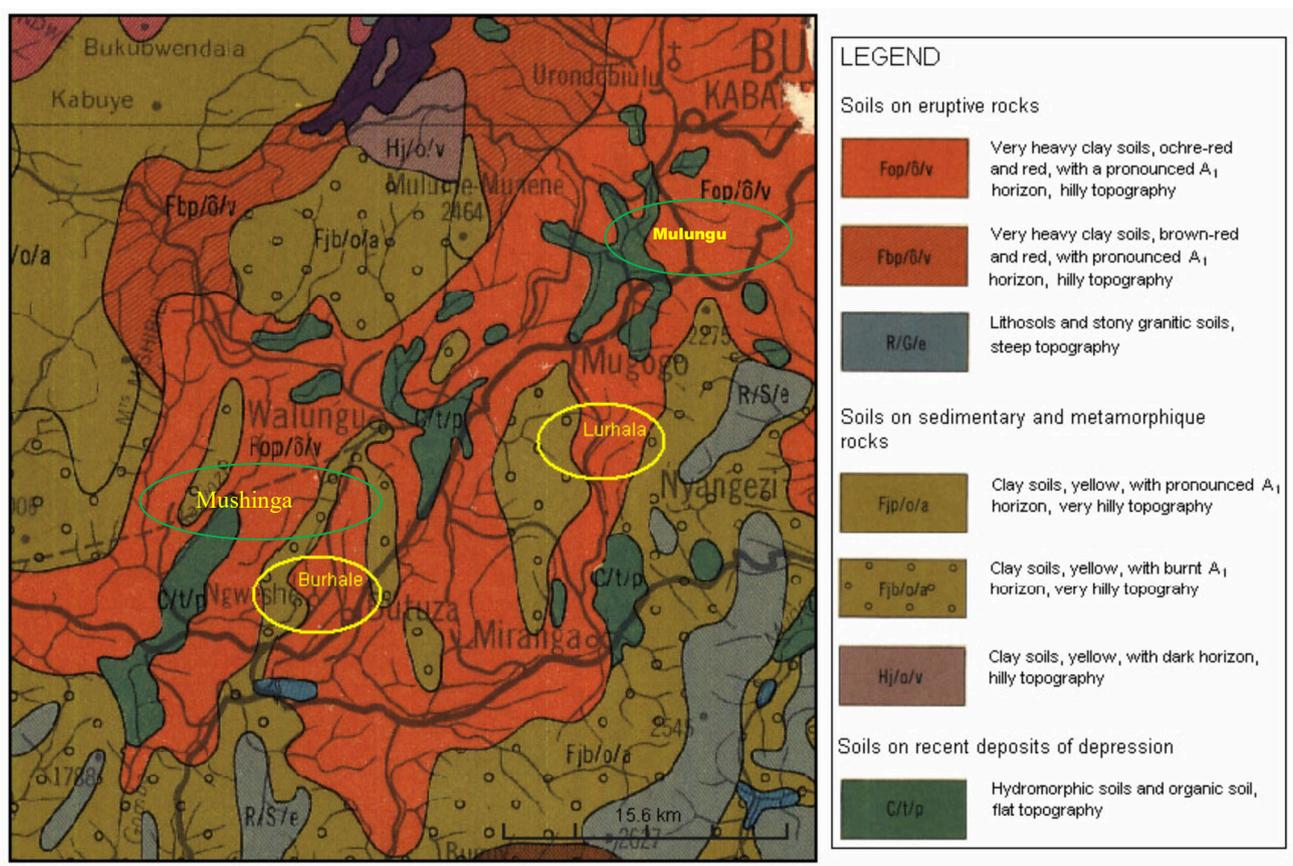


Fig. 1. Sites soils characteristics (Dorsale de Kivu)

The results in table one show that the soil characteristics in the two experimental sites are different. PH, nutrient levels and texture are significantly different. The percentage of sand in the soil of Mushinga is significantly higher than that of Mulungu, while that of Mulungu contains more clay and silt. These results corroborate those obtained by [22] who state that Mulungu soils contain more clays than Mushinga soils.

2.2 MATERIAL

The planting material used consisted of four species of shrubs / leguminous trees and four species of grasses. The four species of shrubs were : *Calliandra calothyrsus*, *L diversifolia*, *L leucocephala* and *A chinensis*.

2.2.1 CALLIANDRA CALOTHYRSUS MEISSN

It is a small tree (2-12 m high), with a trunk diameter of up to 30 cm, with white to red brown bark and a dense canopy. Leaves are bipinnate and alternate; the rachis is 10-19 cm long, without glands; pinnae are (3)-6-20 jugate; rachilla are 2-11 cm long; there are 19-60 pairs of leaflets; leaflets are linear, oblong and acute, 5-8 x 1 mm. Inflorescences are particulate with flowers in umbelliform clusters of 10-30 cm length. Flower sepals and petals are green, calyx 2 mm long, corolla 5-6 mm long. The numerous red stamina filaments are 4-6 cm long. Fruits are broadly linear, flattened, 8-11 cm x 1 cm linear oblong with thickened and raised margins, finely pubescent or glabrous, brown dehiscent, 8(12) seeded. Seeds are ellipsoid, flattened, 5-7 mm long and mottled dark brown [11].

2.2.2 LEUCAENA DIVERSIFOLIA

The specific name 'diversifolia' means 'with leaves of different shapes on the same individual'; from the Latin 'diversus' (divergent) and 'folium' (leaf).

Leucaena diversifolia is a tree or erect shrub, 3-20 m tall, with a single stemmed bole 20-50 cm in diameter, slender and clear up to 10 m in height, ascending branches with horizontal twigs. Bark on young branches smooth, rougher on bole, grey-brown with shallow rusty orange-brown vertical fissures; slash green then cream. Leaves with (min. 14) 16-24 (max. 28) pairs pinnae; pinnular rachis (min. 3.5) 5-7 (max. 8) cm long, densely covered with white hairs; leaflets (min. 2.9) 4-5.5 (max. 7) mm long, (min. 0.6) 0.8-1 (max. 1.2) mm wide, (min. 43) 48-58 (max. 62) pairs per pinna, linear-oblong, acute at apex, strongly asymmetric at base, glabrous except for hairy margins. Flower heads 11-15 mm in diameter, the buds loosely packed; 45-90 flowers per head, in groups of 1-5 (max. 7) in leaf axils, on actively growing indeterminate shoots, the leaves developing with flowers; stamen filaments, anthers and style white, pale pink, sometimes bright shocking pink, and occasionally bright scarlet; anthers sparsely hairy at the tip. Pods 1-6 (max. 7) per flower head, (min. 7) 10-13 (max. 15.5) cm long, (min. 11) 13-16 (max. 17) mm wide, narrowly linear-oblong, flat 6-20- seeded, pod walls thin, papery dark brown or reddish-brown, sometimes lustrous, glabrous or covered in dense velvety hairs, opening along both sides. Seeds 4.3-5.5 mm wide, 2.7-3.4 mm long; the smallest of any species of *Leucaena* [12].

Annual dry matter production of the leaves can reach 10-16 t / ha. Incorporated as a green manure, this product adds 72-119kg of nitrogen, 2.5-3kg of phosphorus, 29-60kg of potassium, 47-94kg of calcium and 7.5-18.5kg of magnesium in the soil per ha. This equates to about 10 t / ha of livestock manure per year [12].

2.2.3 LEUCAENA LEUCOCEPHALA

The specific name 'leucocephala' comes from 'leu', meaning white, and 'cephala', meaning head, referring to the flowers. There are 3 recognized subspecies: ssp. *leucocephala*, ssp. *glabrata* (Rose) S. Zárate, and ssp. *ixtahuacana* C. E. Hughes. *Leucaena leucocephala* is a small, variably shrubby and highly branched(ssp. *leucocephala*) to medium-sized tree with a short, clear bole to 5 m, upright angular branching and a narrow open crown (ssp. *glabrata*), 3-15(max. 20) m tall, bole diameter 10-50 cm. Bark on young branches smooth, grey-brown, slash salmon pink, darker grey-brown and rougher with shallow, rusty orange-brown vertical fissures and deep red inner bark on older branches and bole. This evergreen plant is deep rooted. It often has a combination of flowers, immature and mature pods all present on the tree at the same time. Leaves with (min. 4) 6-9 pairs pinnae; pinnular rachis 5-10.2 cm long, leaflets 9-16 (max. 21) mm long, 2-4.5 mm wide, 13-21 pairs per pinna, slightly asymmetric, linear-oblong to weakly elliptic, acute at tip, rounded to obtuse at base, glabrous except on margins. Leaves and leaflets fold up with heat, cold or lack of water. Flower heads 12-21 mm in diameter, 100-180 flowers per head, in groups of 2-6 in leaf axils, arising on actively growing young shoots, flowers white or pale cream-white. Pods (min. 9) 11-19 cm long, (min. 13) 15-21 mm wide, (min. 3) 5-20(max. 45) per flower head, linear-oblong, acute or rounded at apex, flat, 8-18 seeded, mid-to orange-brown, glabrous and slightly lustrous or densely covered in white velvety hairs, papery, opening along both margins. Seeds hard, dark brown with a hard, shining testa, 6.7-9.6 mm long, 4-6.3 mm wide, aligned transversely in pod [12]

2.2.4 ALBIZZIA CHINENSIS

Albizia chinensis is an unarmed, deciduous or evergreen tree with a flat, spreading crown, up to 30(-43) m tall and trunk up to 70(-140) cm in diameter; bark dark gray, rather smooth, densely hooped, lenticellate, thin; live bark 5 mm thick, pinkish-red. Branchlets slightly angular in the distal parts, terete, puberulous to tomentose, glabrescent. Leaves bipinnate; stipules auriculate, very prominent, 1-1.5 cm x 0.6-3 cm, caducous, pinkish-orange, pubescent, with filiform tail, base much dilated at one side; rachis stout, 10-25 cm long, lenticellate, sparsely and minutely tomentellous, glabrescent, with an elliptical, raised gland near the base of 2-3 mm x 1-1.5 mm; pinnae 4-14(-20) pairs, 4-14 cm long, puberulous to tomentose, glabrescent, with glands at the junctions of the 1 or 2 distal pairs of leaflets, narrowly elliptical to slit-like, concave, 1 mm long, glands sometimes absent; leaflets (10-) 20-30(-45) pairs per pinna, opposite, sessile, thinly chartaceous, asymmetrically subulate, 6-10 mm x 1.5-3 mm, apex sharply acute, base obtuse, oblique, midrib close to the upper margin, sparsely sericeous or glabrous on either side. Inflorescence consisting of pedunculate glomerules (heads) aggregated into terminal, yellow-green, tomentose to hirsute panicle; peduncle 1-3 cm long, up to 5 in clusters, often with auriculate stipules at base; glomerule composed of 10-20 flowers; flowers pentamerous, dimorphic; in a glomerule the central flower is male, the marginal flowers are bisexual; calyx tubular to narrowly funnel-shaped, 2.5-5 mm long, tomentose to hirsute, ending in small triangular teeth; corolla funnel-shaped, 6-10 mm long, puberulous to hirsute especially on the lobes, lobes triangular-ovate, acute; stamens numerous, 2 cm long, at the base united into a tube as long as or slightly longer than the corolla tube; ovary glabrous, sessile. Pod thin, flat, strap-shaped, 6-20 cm x 2-3 cm, often with slightly sinuate margins, indehiscent or breaking irregularly, reddish or yellowish-brown, glossy, 8-12 seeded. Seed flattened ellipsoid, 7(-10) mm x 4-6 mm x 0.5-1 mm, dull dark brown, areole nearly circular, 1 mm in diameter [12].

The different species of grasses used were: setaria, pennisetum, tripxacum and brachiaria.

2.2.5 SETARIA SPHACELATA

It is a perennial grass often growing up to 2 m tall, and occasionally reaching up to 3 m in height. Its green or somewhat bluish-green leaves are elongated in shape (10-50 cm long 3-17 mm wide) and mostly hairless. Its spike-like seed-heads (7-50 cm long) have densely clustered flower spikelets borne in small groups. Each group of spikelets is subtended by a ring of 6-15 golden yellow bristles (4-12 mm long). when the seeds are shed from the seed-head, the subtending bristles are left behind.

The upright (i.e. erect) flowering stems (i.e. culms) are usually green and hairless (i.e. glabrous).

The green or somewhat bluish-green (i.e. glaucous) leaves consist of a sheath, which encloses the stem, and a spreading leaf blade. The leaf sheaths are smooth and hairless (i.e. glabrous), but where they meet the leaf blade there is a line of hairs (i.e. ciliate ligule) about 1.5 mm long. The elongated (i.e. linear) leaf blades (10- 50 cm long 3-17 mm wide) are soft and mostly hairless (i.e. glabrous) with entire margins and long pointed tips (i.e. acuminate apices).

The upright (i.e. erect) seed-heads are spike-like in appearance, but actually consist of numerous very short branches that are held closely to the stem (i.e. they are spiciform panicles). These seed-heads (7-50 cm long and about 8 mm wide) have numerous densely clustered flower spikelets that are borne in small groups of one to four. Each group of spikelets is subtended by a ring (i.e. involucre) of 6-15 golden yellow bristles (4- 12 mm long). The individual flowers spikelets (1.25-3.5 mm long) are oval (i.e. elliptic) in shape and consist of a pair of bracts (i.e. glumes) and two tiny flowers (i.e. florets). The lower floret has only male flower parts, while the upper floret has both male and female parts (i.e. it is fertile or bisexual). The fertile florets have three stamens and a purple or white two-branched feathery stigma Flowering occurs mainly during summer. The 'seed' (i.e. caryopsis or grain) remains contained within the remains of the old flower spikelets. When these 'seeds' are shed from the seed-head, the subtending bristles are left behind.

This species reproduces only by seed. Seeds are commonly spread through the deliberate cultivation of this species as apasture grass, and in contaminated agricultural produce (e.g. fodder). They may also be dispersed by wind, seed-eating (i.e. granivorous) birds and water [17].

2.2.6 PENNISETUM PURPUREUM

It is a Poaceae (Gramineae)/Grass Family. Robust perennial to 4 m tall, forming thick clumps or colonies from basal offshoots or short rhizomes. Stems often branched above; internodes more or less bluish glaucous; young nodes with white hairs, later becoming smooth, glabrous. Leaf sheaths glabrous, usually shorter than the internodes; ligule a narrow rim densely fringed with long white hairs. Leaf blades linear to tapering, flat, often bluish green, to 1 m (39 in) long and 3 cm (1 in) wide, pilose near the base, especially on margins; blade margins generally rough; midvein stout, whitish above, strongly keeled below. Inflorescence a dense terminal panicle, spike-like, bristly, tawny to purple-tinged, to about 20 cm (8 in) long and 2 cm (0.8 in)

across. Spikelets 4-6 mm long, solitary or in clusters of 2-6 on hairy axis, surrounded by sparsely plumose bristles to 2 cm long that fall with the spikelets at maturity; outermost glume minute or absent.

2.2.7 TRIPSACUMLAXUM

Tripsacum laxum Nash) is a robust, strongly rhizomatous, tufted and leafy perennial grass that can form large bunches. The stems can be up to 3.5-4.5 m high and up to 1-5 cm in diameter. They develop at a very late stage and Guatemala grass remains leafy for a long time. The roots are shallow and the plant does not grow well during a long dry season. As the grass matures, the roots become stronger and store nutrients that will be necessary for regrowth after cutting. The leaves are tall (0.4-1.2 m long x 9 cm broad), glabrous or sparsely hairy. The inflorescences are subdigitate with 3 to 8 slender, elongated racemes, up to 20 cm long, containing male and female spikelets (3-5 mm long). Flowers are mostly sterile and Guatemala grass is usually propagated by stem cuttings or tuft division [23].

Guatemala grass is cultivated primarily for fodder in cut-and-carry systems. It can also be used to make silage. Guatemala grass provides several environmental benefits, notably against soil erosion and the development of pests and diseases in neighbouring crops.

2.2.8 BRACHIARIA RUZIZIENSIS

Brachiariaruziziensis belongs to the Poaceae family, Panicoideae subfamily and the Paniceae tribe. A tufted grass, Congo grass is a creeping perennial that has short rhizomes which form a dense leafy cover over the ground. Stems of the plant arise from many-noded creeping shoots and short rhizomes and then when fully grown reach a height of 1.5 m when flowering. The leaves of this grass are soft but hairy, with an average width of 15mm, length of 25mm and a seed weight of 250,000/kg. The seeds should be drilled into a well prepared seed bed, sowing in rows that are spaced 60 cm apart and it can be grazed upon as soon as it is ready [24].

2.3 METHODS

2.3.1 EXPERIMENTAL DESIGN

Different species of grasses and shrubs were planted on two sites with degraded soils in stations and on farm.

The experimental field was divided into four randomized blocks each containing 8 plots of 10 mx10m corresponding to four grass species and four other shrub species and separated by 3m paths. Each plot was crossed by 10 lines of hedges of one of the four grasses (*Pennisetum purpureum*, *Setaria sphacelata*, *Brachiaria ruziziensis* and *Tripsacum laxum*) or shrubs (*Leucaena diversifolia*, *Calliandra calothyrsus*, *Albizzia chinensis* and *Leucaena leucocephala*). Hedges were planted every 1m perpendicular to the slope. Grasses were planted at 1 x 0.25m intervals while shrubs were 1 x 0.5m. The eight plots of all species were repeated four times in each site.

Grasses were cut 20 cm above the ground every 2 to 3 weeks using a machete to recycle all the biomass for the herbaceous.

Manure (20 t MS / ha) and micro doses of NPK fertilizer (50 kg / ha-1) were applied. In the case of shrubs, they were cut at 50 cm from the soil level during field preparation for planting annual crops and 3 months after planting crops in order to reduce competition between them and annual crops, at each cut the amount of biomass cut was weighed using a scale.

2.3.2 OBSERVATIONS

For comparing the production of different species of grasses and shrubs, observations were made on the quantities of cut biomasses. Cut shrubs and grasses were weighed to obtain the amount of biomass produced per species. To obtain the dry matter, the samples were dried in an oven at 100°C for 48 hours.

2.3.3 DATA ANALYSIS

The data analysis was done by software R. It consisted of the examination of the multivariate variance (Multifactor ANOVA). For the comparison of means between forage species and between sites, Tukey's (honestly significant difference) (HSD) test at p value 0.05 was used.

3 RESULTS

3.1 BIOMASS PRODUCTION BY GRASSES (GRAMINEAE) AND FORAGE LEGUMES AT TWO SITES WITH CONTRASTING SOILS

The average quantity of above ground biomass produced by four forage gramineae species at two sites with contrasting soils are presented in Table 2 below.

Table 2. Average quantity of above ground biomass produced by four forage grass species during three cuts at two sites with contrasting soils at Mulungu and Mushinga

Sites	Species	Cut1(kg FM/plant)	Cut 2 (kg FM/plant)	Cut 3 (kg FM/plant)	Total (kg FM/plant)	Yield DMt/ha
Mulungu	P. purpureum	4.1 a#	4.0 a	3.3 a	11.2 a	33.7 a
	S. sphacelata	3.4 b	2.8 b	2.4 b	8.3 b	24.9 b
	T. laxnum	3.4 b	2.2 d	1.8 c	7.3 c	18.3 c
	B. ruziziensis	2.9 c	2.5 c	1.9 c	7.2 c	18.0 c
	Average	3.5	2.9	2.4	8.5	23.7
Mushinga	P. purpureum	2.9 c	2.8 b	2.6 b	8.3 b	24.9 b
	S. sphacelata	1.9 d	1.6 e	1.3 d	4.7 d	14.1 d
	T. laxnum	1.5 e	1.3 f	1.0 e	3.7 e	9.3 e
	B. ruziziensis	1.5 e	1.3 f	1.1 e	3.9 e	9.7 e
	Average	2.0	1.8	1.5	5.2	14.5

#:The numbers followed by the same letter in the same column are not significantly different according to the Tukey test $p < 0.05$. FM: Fresh matter, DM : Dry Matter.

The analysis of results summarized in Table 2 and 3 show that the sites have a highly significant effect ($p = 0.001$) on the forage aboveground biomass yield per plant and per hectare for the different forage species. The biomass produced per plant per cut as well as the total biomass produced per plant and the yield per ha for all the different cuts and species at Mulungu were significantly ($p = 0.001$) high than those produced at Mushinga. The total quantity of biomass produced per plant at Mulungu ranged from 7.2 to 12.2 kg of Fresh Matter as opposed to Mushinga, ranging from 3.7 to 8.3 kg of Fresh Matter per plant for gramineae (Table 2). The same trend was observed for the biomass yield produced per hectare. The yield for Mulungu varied between 18.0 and 33.7 t/ha of dry matter, contrary to Mushinga, it varied between 9.3 and 24.9 t/ha of dry matter 3 for gramineae (Table 2).

The similar tendence was observed for shrubs forage species. The different quantities of biomass (fresh matter) yield per plant varied from 1.6 to 7.8 kg per plant for the Mulungu site, from 1.3 to 5.2 kg/plant for Mushinga (Table 3). In addition, the average biomass yield of dry matter per hectare produced per the different species of shrubs at Mulungu was higher in comparison with Mushinga yield. It varied between 2.6 and 13.1 t/ha of dry matter and between 2.1 and 8.5 t/ha of dry matter respectively for Mulungu and Mushinga (Table 3).

The average quantities of aboveground biomass produced by four forage legume shrubs at two sites with contrasting soils in South Kivu province are presented in Table 3 below.

Table 3. Aboveground biomass quantities produced by four species of forage legume shrubs intercropped at Mulungu and Mushinga

Sites	Species	Cut1(kg FM/plant)	Cut 2 (kg FM/plant)	Cut 3 (kg FM/plant)	Total (kg FM/plant)	t DM/ha
Mulungu	C. calothyrsus	2.7 a	2.8 a	2.4 a	7.8a	13.1a
	L.diversifolia	1.9 b	2.2 b	2.0 b	6.2b	10.3b
	L.leucocephala	0.7 d	0.6 e	0.5 e	1.9e	3.1e
	A.chinensis	0.6 de	0.6 e	0.5 e	1.6 ef	2.6ef
	Average	1.5	1.5	1.3	4.4	7.3
Mushinga	C. calothyrsus	1.9 b	1.8 c	1.6 c	5.2c	8.7c
	L.diversifolia	1.3 c	1.2 d	1.1 d	3.6d	5.9d
	L. leucocephala	0.6 de	0.4 f	0.3 f	1.3f	2.1f
	A.chinensis	0.5 e	0.4 f	0.3 f	1.3f	2.2f
	Average	1.1	1.0	0.8	2.8	4.7

#:The numbers followed by the same letter in the same column are not significantly different according to the Tukey test $p < 0.05$. FM: Fresh matter, DM : Dry Matter.

3.2 SUMMARY OF ANALYSIS OF VARIANCE FOR AVERAGE BIOMASS PRODUCTION

Table 4. Summary of Analysis of Variance (P-Values)

Species	Source of variation	Cut1(kg FM/plant)	Cut 2 (kg FM/plant)	Cut 3 (kg FM/plant)	Total (kg FM/plant)	Yield t/ha
Gramineae	Species	0.001***	0.001***	0.001***	0.001***	0.001***
	Sites	0.001***	0.001***	0.001***	0.001***	0.001***
	Species * sites	0.023 ns	0.472 ns	0.113 ns	0.400 ns	0.224 ns
Shrubs	Species	0.001***	0.001***	0.001***	0.001***	0.001***
	Sites	0.001***	0.001***	0.001***	0.001***	0.001***
	Species * sites	0.001***	0.001***	0.001***	0.001***	0.001***

*** = very highly significant difference at $p < 0.05$; ns = not significant.

The analyze of variance summarized in this table, show the higher interaction between sites and species aboveground biomass production for forage shrubs species. However, there was no significant interaction between sites and species for gramineae species. In addition the biomass yield was significantly higher between the different species gramineae and shrubs legumes forage.

3.3 ABOVEGROUND BIOMASS PRODUCTION BY GRAMINEAE SPECIES FORAGE

Figure 2 illustrates the results of observations on average aboveground biomass production by forage grass species in South Kivu.

The results of observations presented in Figure 2 show that Pennisetum stood out very widely, it produced an average amount of biomass in DM highly superior ($P < 0.001$) to those of three others followed by Setaria, Brachiaria and Tripsacum. The classification of these species would be as follows: pennisetum>setaria>Brachiaria = tripsacum (Figure 1).

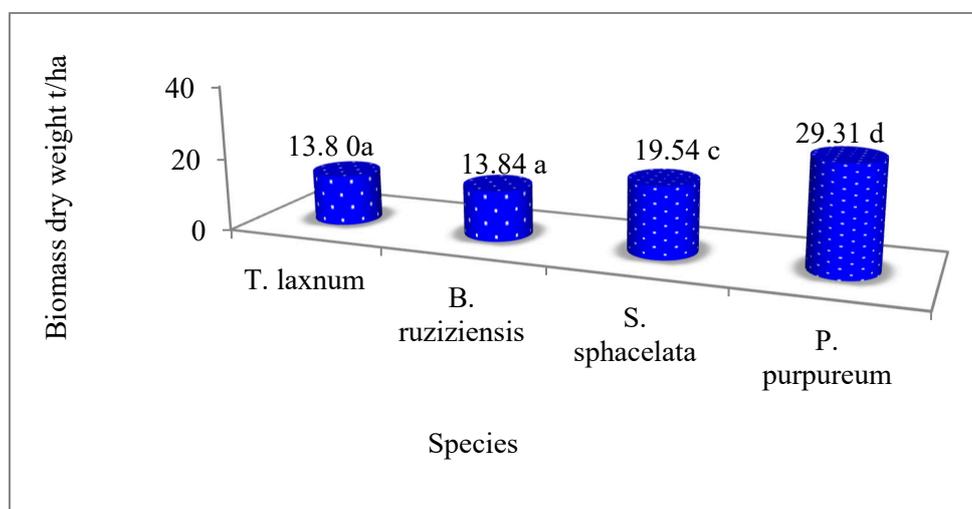


Fig. 2. Aboveground biomass production by forage grass species in South Kivu. The bars with the different letters with 2 values compared indicate a very highly significant difference according to the Tukey's HSD test ($p < 0.05$)

3.4 ABOVEGROUND BIOMASS PRODUCTION BY FORAGE SHRUBS SPECIES

Figure 3 shows the results of observations on average aboveground biomass production by forage shrubs species in South Kivu.

The results of observations presented in Figure 3 show that Calliandra stands out very widely, it produced an average amount of biomass in MS / ha highly superior ($P < 0.001$) C calothyrsus to those of three others followed by L diversifolia, L leucocephala and last position A chinensis. The classification of these species would be as follows: Calliandra> L diversifolia> L leucocephala> A chinensis (Figure 3). Figure 3 clearly shows that L. leucocephala and A. chinensis shrubs, although successful in the Kisangani environment (very hot wetland), are unsuitable in mountainous Kivu (wet and very cool zone).

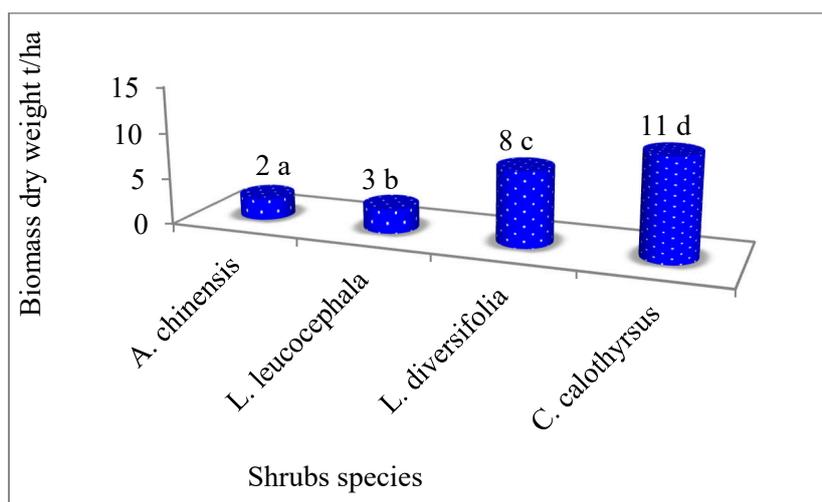


Fig. 3. Aboveground biomass production by forage grass species in South Kivu. The bars with the different letters with 2 values compared indicate a very highly significant difference according to the Tukey's HSD test ($p < 0.05$)

4 DISCUSSION

4.1 BIOMASS PRODUCTION BY GRASS AND FORAGE SHRUB SPECIES IN INTERCROPPING AT TWO SITES WITH CONTRASTING SOILS

All forage species yielded higher biomass yields in the Mulungu site with a higher clay content than Mushinga with a higher sand content.

The difference in biomass yield between different species at both sites may be due to specific performance. Some studies have shown that the dry matter production of grass species depends positively on the level of nitrogen and soil fertility, this would be the case of the difference between the yields of different species on the two experimental sites which gives a higher yield at Mulungu with soil with a higher fertility level than Mushinga (Table 1).

4.2 ABOVE GROUND BIOMASS PRODUCTION BY GRASS SPECIES AND SHRUBS FORAGE LEGUMES

The amount of biomass produced by pennisetum for all observed parameters was greater than that produced by setaria and tripsacum and brachiaria. The appearance of diazotrophic bacteria associated with pennisetum purpureum, as indicated in previous studies [25], indicates that biological nitrogen fixation may play an important role in the nitrogen supply of this crop in poor soils. In addition, some plant species may have high productivity due to good assimilation coefficients, good photosynthetic activity and well adapted root development, but yield cannot increase significantly on degraded soils without fertilizer.

For shrubs, calliandra produced a large amount of biomass compared to other species. These results are similar to those obtained by [9] who have shown that Calliandra produces more biomass than other species in some sites in the South Kivu province. For the production of forages biomass, We can classify in different classes the different species: Fodder producing more biomass; the calliandra, middle class; L diversifolia and the class of low production; L. leucocephala and Albizzia, these results corroborate those found by [9].

5 CONCLUSION

The aboveground biomass yield is influenced by site soil characteristics. Some forage species produced a highest biomass yield in the two sites. It is mainly *Calliandra calothyrsus* and *Leucaena diversifolia* for leguminous shrubs, but also *Pennisetum purpureum* and *Setaria sphacelata* for forage grasses.

For forage biomass production and restoration productivity on degraded soils, *Calliandra calothyrsus* or the combination of *Calliandra calothyrsus* and *Leucaena diversifolia*, and *Pennisetum purpureum* alone or in the combination *Pennisetum purpureum*-*Setaria sphacelata* can be used as shrubs leguminous and grass species fodder in the conditions of the Province of South Kivu and especially in the territories of Kabare and Walungu. These four species have been retained in the continuation of soil fertility restoration trials at both sites.

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