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Herbaceous Forage Legumes Adaptation in Acidic Soils in South-Kivu, D. R. Congo

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Abstract

In D. R. Congo, agriculture is still managed in extensive system with crop integration especially in South-Kivu Province. Demographic pressure on the land is highly due to unequal distribution.

The objective of this study is to test adaptation of improved herbaceous forage legumes selected in Tropical America by "Centro International de Agricultura Tropical" (CIAT). Agronomic performance and farmer participatory evaluation in using various agroecological zones in South-Kivu, were used to draw a model for similar areas. Forages were installed randomly in the blocks with 3 replicates. In spite of the acidic soils, forages recommended were, *S. guianensis* 11995, *S. guianensis* Cook, *C. molle* and *D. intortum*. The second step should be to adapt these forages in the farmers cropping systems. The seasons didn't influence in general the yield production. All the accessions of *V. unguiculata* and *C. ternatea* did not adapt anywhere and *C. brasiliensis* was sensitive to diseases and insects.

Keywords: Herbaceous forage legumes, Adaptation, Farmers participatory evaluation, D. R. Congo

1. Introduction

The world population passing seven billion in 2011 can exceed nine billion by 2050. Human consumption will increase and the challenge will be to face malnutrition and ensure a sustainable food production and environment. While the intensification pathway would require a significant input of fertilizers and agro-chemicals, the environmental costs of these inputs are likely to be small compared with the impacts of increases in greenhouse gases and loss of biodiversity form the land expansion pathway (Keating et al., 2013). Designing ecologically intensive systems imposes on agronomists the need to move beyond optimizing current processes, to design of the structures that support such processes (and new ones) in space and time. The diversity, special heterogeneity and temporal dynamics of smallholder farming systems in the humid highlands of Africa call for the flexible, adaptive targeting of politics, management practices and technologies (Titonell, 2013). In D.R. Congo, agriculture is still managed in extensive system with crop integration especially in South-Kivu Province (Cox, 2012; Ouma et al., 2012). Demographic pressure on the land is highly due to unequal distribution. However, the environment enduring insecurity, wars, animals looting and poverty challenges any new research initiative (Maass et al., 2012). There are low crop productions due to poor soil management, small homelands of farmers, lack of extension services, leading to alarming nutritional status (Katunga, 2004). Livestock productivity is low, especially during the dry season. The forage crops are not practiced yet to feed small animals (Katunga, 2013) whereas improved forages could play an important role to both enhance livestock production and improve soil fertility and also prevent from soil erosion. This study aimed at testing adaptation of improved herbaceous forage legumes selected in Tropical America by "Centro International de Agricultura Tropical" (CIAT). Agronomic performance and farmer participatory evaluation in using various agroecological zones in South-Kivu, were used to draw a model for similar areas.

2. Material and Methods

2.1 Agronomic Evaluation

The trial was installed in October, 2010 at both sites with poor soils. Table 1 indicates the location and some characteristics of the sites.

Table 1. Location of the experimental sites and some characteristics

Site	Latitude	Longitude	Elevation (m asl)	Soil fertility	Population (number of inhabitants)
Nyangezi	2.88°S	27.03°E	1580	pH 3.94, CEC 3.0	39,782*
Tubimbi	2.79°S	23.59°E	1100	pH 4.45, CEC 4.0	23,630*

* (SNS 2011).

Seeds of the experimental fodders came from CIAT Columbia. They were *Canavalia brasiliensis* CIAT 17009, *Centrosema molle* CIAT 15160, *Clitoria ternatea* CIAT 20692, *Lablab purpureus* (CIAT 21603 and CIAT 22759), *Stylosanthes guianensis* (CIAT 11995 and

ILRI 4 Cook), *Vigna unguiculata* (CIAT IT95K52-34, CIAT IT97K1069-6 and CIAT IT98K131-2) and *Desmodium intortum* as a local control. Four handshakes of cow manure were placed in the hole before the plantation at the two sites. Forages were installed randomly in the blocks with 3 replicates. Every plot measured 3 m × 3 m. The seedling were set in line with a spacing of 0.25 m and 0.5 m between lines. At average 50% flowering in all plots, regularization cuttings were made in January, 2011 in Nyangezi and Tubimbi. Leaves were removed off stems and were weighed separately for the herbaceous with little stems (*Canavalia brasiliensis, Clitoria ternatea, Lablab purpureus, Vigna unguiculata*). After every harvest, all other lines of the useful plot and borders were cut (Schultz-Kraft &Toledo, 1990; Rabaoc, 1998). Six overall cuttings were made over eight weeks. A homogeneous fresh sample of about 300 g leaves and 300 g of stems by accession and / or specie was taken at every harvest and was put until constant weight during at least three months in a sun drier that reached 40-45 °C in brightened time. The mean fresh leaves and stems (only for the herbaceous with little stems) yield (MFLSY) in kg ha^{-1} = Fresh leaves and / or stems for some forage (g) × Dry mater (%) / Su (m^2) × 10, (Katunga, 2004), Su is the net plot size m^2. Samples have been analyzed on reflectance spectroscopy for nutrient contents (DM, OM, CP, ADF, ADL and TIVOMD) at the International Livestock Research Institute (ILRI) in Addis-Abeba, Ethiopia.

2.2 Farmers Participatory Evaluation

Farmers evaluation was done during the rainy and dry season at both sites with 5 women and 5 men per location and season indicating preferences according to own criteria. Farmers selected plots by dropping a white paper. Data were presented as ranks of preference at the location. After the choice of forages, the two teams gathered to discuss and reach a gender consensus (Stür et al., 2002).

2.3 Data Analysis

Descriptive statistics were computed and differences of MFLSY were established by Analysis of variance (ANOVA), graphs in STATVIEW software, Cluster analyses and Correspondence analyses in Past Software.

3. Results

3.1 Agronomic Evaluation

3.2 Nutritive Values of Forages

Table 2. Chemical analyses of forages at both sites (%)

	Nyangezi					Tubimbi				
Légumineuses herbacées	DM*	OM	CP	ADF	TIVOMD	DM	OM	Cp	ADF	TIVOMD
C. brasiliensis 17009	22.7	82.6	23.5	30.5	75.5	21.7	81.2	22.7	31.3	73.3
C. molle 15160	29.2	90.9	11.4	36.1	66.4	25.1	87.2	19.3	38.8	68.8
C. ternatea 20692	22.4	89.6	22.5	30.7	72.8	19.6	94.3	14.9	40.3	61.4
D. intortum	23.4	91.5	16.3	33.3	63.8	21.3	89.9	17.5	34.5	64.5
L. purpureus 22759	21.1	87.9	25.5	24.9	74.3	24.3	86.6	24.9	28.2	74.1
L. purpureus 21603	22.4	87.5	25.4	27.7	72.5	23.7	88.5	25.3	28.4	74.2
S. guianensis 11995	25.1	89.9	19.2	39.8	62.8	23.2	89.9	20.1	38.9	65.9
S. guianensis Cook	23.5	90.3	20.1	43.1	60.7	24.4	91.1	22.2	36.9	64.4
V. unguiculata 131-2	32.9	87.7	26.2	31.7	75.2	32	85.8	24.2	34	74.7
V. unguiculata 52-34	35	83.9	27.4	33.4	73.8	32.9	85	24.6	35.9	73
V. unguiculata 1069-6	33	83.7	26.7	32.6	74.7	33.9	85.6	25.3	34.5	71.2

*DM=Dry mater, OM= Organic matter, CP=Crude proteins, ADF=Acid Detergent Fiber, TIVOMD = True *In Vitro* Organic Mater Digestibility.

The nutritive values of the forages were in general very good, CP of all the forages varied in Nyangezi between 16 to 27% except 11.4% for *C. molle*, but it was very good in Tubimbi. Digestibility is very good at both sites. In Nyangezi ADF is in general lower than in Tubimbi, good forages reached at least 30%.

3.3 Diseases and Insects

Table 3 shows the scores of diseases and insects.

Table 3. Ranks of diseases and pests

Forage herbaceous legumes	Nyangezi		Tubimbi	
	Diseases	Pests	Diseases	Pests
C. brasiliensis 17009	3	2	3	2
C. molle 15160	2	2	1	1
C. ternatea 20692	3	2	3	1
D. intortum	2	2	2	2
L. purpureus 21603	3	2	2	2
L. purpureus 22759	2	2	2	2
S. guianensis 11995	1	1	1	1
S. guianensis Cook	1	1	1	1
V. unguiculata 52-34	4	3	4	2
V. unguiculata 1069-6	4	3	4	2
V. unguiculata 131-2	4	3	4	2

In general, the forages were not considerably attacked by diseases and pests. Fodders that had the score 1 meaning without impact of diseases and pests in Nyangezi and Tubimbi were *S. guianensis* and *S. guianensis* Cook. Forages fairly attacked by diseases and insects, rank 2 in Nyangezi were *L. purpureus* 22759, *C. molle* and *D. intortum* and for Tubimbi *D. intortum, L. purpureus* 21603 and *L. purpureus* 22759. Fodders most attacked by diseases and insects, ranks 3 and 4 were also observed in Nyangezi occurred for 3 *C. brasiliensis C. ternatea, L. purpureus* 21603 and pests *V. unguiculata* 1069-6, *V. unguiculata* 131-2 and *V. unguiculata* 52-34. In Tubimbi with the rank 3, for diseases were *C. brasiliensis* and *C. ternatea*, the rank 4 was observed in the two sites on diseases with *V. unguiculata* 1069-6, *V. unguiculata* 131-2 and *V. unguiculata* 52-34.

The following figures show the height and recovery of forages at the sites.

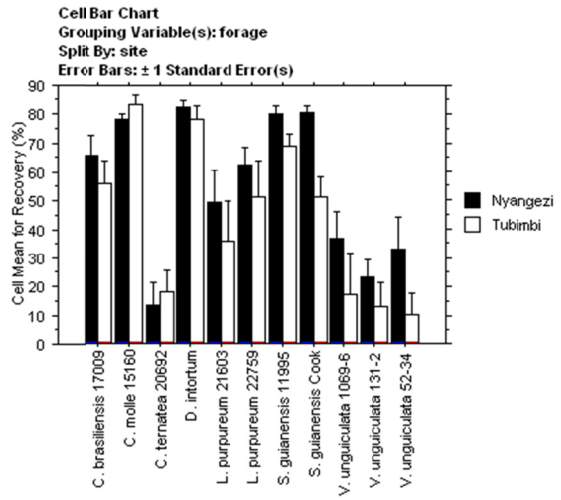

Figure 1. The recovery of the forages (%)

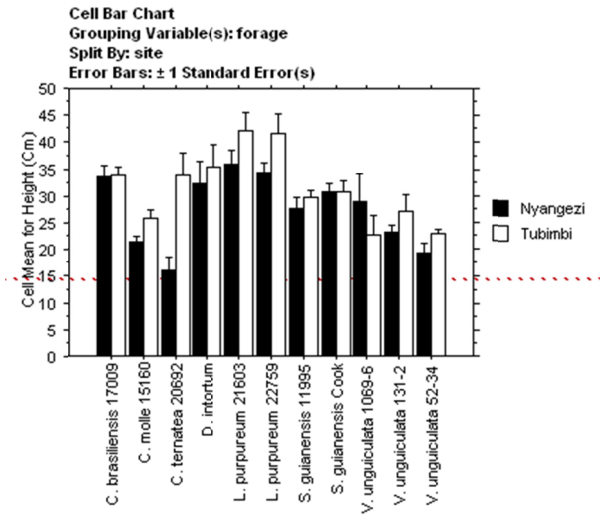

Figure 2. The height (cm) of forages

In Nyangezi the best recovery was performed by *D. intortum*, *C. brasiliensis*, *C. molle*, *L. purpureus* 22759, *L. purpureus* 21603, *S. guianensis* 11995, *S. guianensis* Cook and in Tubimbi *C. brasiliensis*, *C. molle*, *D. intortum*, *L. purpureus* 22759, *S. guianensis* 11995 and *S. guianensis* Cook. Forages with a better height were in Nyangezi *C. brasiliensis, D. intortum*, *L. purpureus* 22759, *S. guianensis* 11995, *S. guianensis* Cook and *V. unguiculata* 1069-6 and Tubimbi *C. brasiliensis*, *C. molle, D. intortum, L. purpureus* 22759, *S. guianensis* 11995, *S. guianensis* Cook and *V. unguiculata* 131-2. In Nyangezi there is a significant difference of recovery rates between the forages ($P<0.05$) whereas for the height there was no significant difference ($P>0.05$). In Tubimbi the rates of recovery and height did not differ between the forages ($P>0.05$).

3.4 Biomass Production

Table 4 shows the total biomass fresh and stems yield according to seasons.

Table 4. Yield production per season (MFLSY means kg ha^{-1})

Herbaceous legumes	Rainy season Nyangezi	Tubimbi	Dry season Nyangezi	Tubimbi
C. brasiliensis 17009	950.0±945.8ab	586.0±503.4ab	300.1±207.3bc	513.0±257.1ab
C. molle 15160	1000.0±353.4ab	1226.0±677.1a	572.0±22.1ab	1814.0±1263.2a
C. ternatea 20692	62.0±89.3bc	130.8±261.6bc	n.m*	n.m
D. intortum	1316.0±1147.8ab	918.0±797.3ab	392.0±221.4bc	573.0±457.9b
L. purpureus 21603	368.0±386.8bc	182.0±137.7bc	47.0±0bc	n.m
L. purpureus 22759	568.0±402.1b	484.0±429.5b	563.0±218.9b	n.m
S. guianensis 11995	1807.0±1639.7a	1055.0±472.7ab	1188.0±204.5a	325.0±363.9ab
S. guianensis Cook	1593.0±809.7ab	1128.0±660.2ab	721.0±370ab	466.0±191.7ab
V. unguiculata 1069-6	88.0±94.5bc	64.0±59.5bc	n.m	n.m
V. unguiculata 131-2	42.0±16.1bc	65.0±80.4bc	n.m	n.m
V. unguiculata 52-34	190.0±171.3bc	132.0±193.4bc	n.m	n.m
Lsd (p<0,05)	1130.5	689.2	580.2	1162.3

n.m*=not mentioned.

According to seasons, Turkey test gathers means in two classes. There is a highly significant difference (P<0.001) between the production of the biomass in rainy season in Nyangezi and Tubimbi. During the dry season, there is a significant difference (P<0.05) between the production of fodders in the dry season. In Tubimbi there is no difference (P>0.05) between the production of fodders in the dry season. At both sites and according to seasons, the means are classified in two groups.

Forages with the best yield in the rainy season were the same at both sites: *C. brasiliensis, C. molle, D. intortum, S. guianensis* 11995 and *S. guianensis* Cook. In the dry season the outcome was the same except for *C. brasiliensis* which performed well only in Tubimbi.

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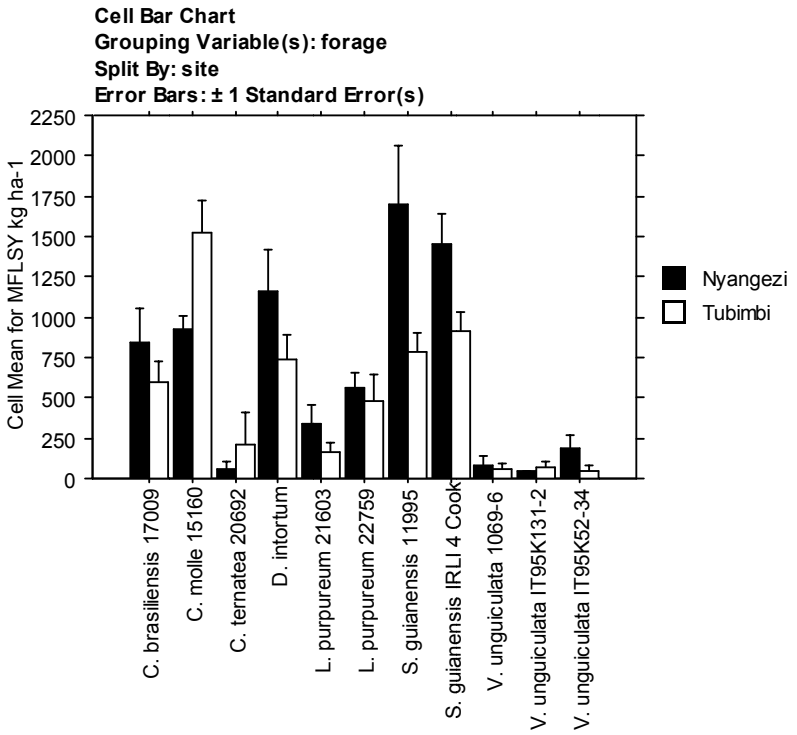

Figure 3. Mean fresh leaves and stems yield per site

The best yield production of forages were in Nyangezi *C. brasiliensis*, *C. molle*, *D. intortum*, *S. guianensis* 11995 and *S. guianensis* Cook and in Tubimbi *C. molle, D. intortum, S. guianensis* 11995 and *S. guianensis* Cook. In Nyangezi there is a significant difference of fodders yield ($P<0.05$) but not in Tubimbi ($P>0.05$).

Figure 4 shows the yield production of forages at both sites.

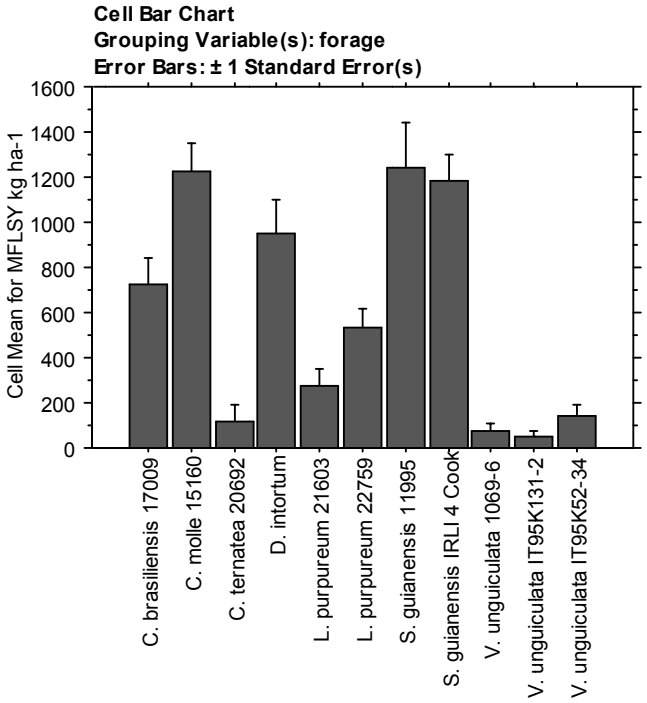

Figure 4. MFLSY in both the sites

At both the sites, the best yield forages were *C. molle, D. intortum, S. guianensis* 11995 and *S. guianensis* Cook. There was a significant difference between the yield production of forages ($P<0.05$).

Figure 5 shows the clusters of forages according quantitative variables.

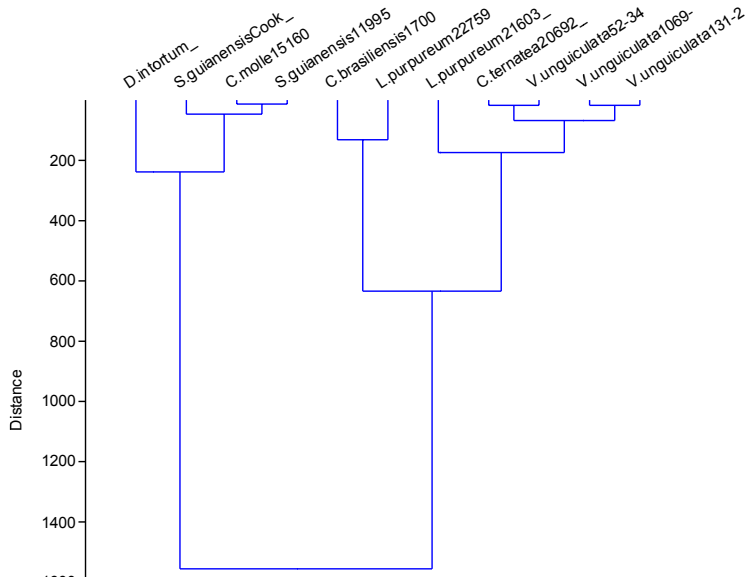

Figure 5. Cluster of forages according quantitative variables

This cluster involved the following quantitative variables : MFLSY, recovery, height, soil pH

and Cp. The eigen value of the two first axes was 99.9%.

The figure shows that fodders are classified in two groups in which the best includes *D. intortum*, *S. guianensis* 11995, *S. guianensis* Cook and *C. molle*.

3.5 Participatory Evaluation 0f Forage Herbaceous Legumes

Table 5 shows the forage choices of the farmers.

Table 5. Ranks of farmers' choice

Forage herbaceous legumes	Rainy saison		Dry saison	
	Nyangezi	Tubimbi	Nyangezi	Tubimbi
C. brasiliensis 17009	1	1	3	2
C. molle 15160	0	4	1	1
C. ternatea 20692	0	0	0	0
D. intortum	0	0	0	3
L. purpureus 21603	4	0	0	0
L. purpureus 22759	0	0	0	0
S. guianensis 11995	3	3	2	4
S. guianensis Cook	2	2	4	0
V. unguiculata 52-34	0	0	0	0
V. unguiculata 131-2	0	0	0	0
V. unguiculata 1069-6	0	0	0	0

*n,m.: not mentioned

In general, the farmer's choice of forages is not different between the two seasons in both sites. The forages chosen are essentially *C. brasiliensis, S. guianensis* Cook, *C. molle,* and *S. guianensis* 11995. Figure 6 shows the correspondence analysis of the fodders chosen by farmers while taking account of gender and the season.

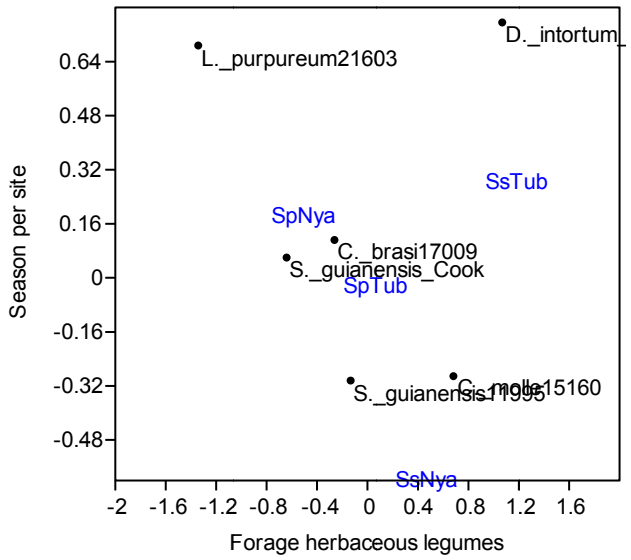

Figure 6. Correspondence analysis of farmer choices

The eigen values of the two first axes were 90.5%. The qualitatives variables observed were: NyaSp=Nyangezi in rainy season, TubSp=Tubimbi in rainy season, NyaSs=Nyangezi in dry saison, TubSs=Tubimbi in dry season.

Figure 6 shows that the choice of *C. brasiliensis* and *S. guianensis* Cook was high in the rainy season at both sites; *S. guianensis* 11995 and C. *molle* in Nyangezi during the dry season.

4. Discussion

In the acidic soils of South-Kivu, *S. guianensis* reached a yield production similar to that in Rwanda (Barahenda et al., 2007). All legume plant, counts among which *S. guianensis* decreased drastically with zero counts during the 3th season in Zimbabwe (Mugabe et al., 2004). Compared to Central America *Canavalia brasiliensis* yield production (Douxchamps et al., 2008) was more than double in South-Kivu. In South Africa some accessions of *Lablab purpureus* produced between 1000 to 7000 kg/ha (Ayisi et al., 2004), which suggests that South-Kivu yield production is among the lowest. Forages with the best yield of biomass were *C. brasiliensis*, *C. molle, D. intortum*, *S. guianensis* 11995 and *S. guianensis* Cook in Nyangezi and they were the same species without *C. brasiliensis* in Tubimbi. This last one was among the forages more attacked by diseases and insects. As *C. brasiliensis* adapted well in Nyangezi and Tubimbi but its sensitivity to diseases leads to scepticism (Katunga, 2013). All the accessions of *V. unguiculata* and *C. ternatea* were not adapted anywhere. Among the forages recommended to farmers in Zimbabwe were *D. intortum, L. purpureus* (Nyoka et al., 2004). There was no significant difference between the rainy and the dry season. In the participatory evaluation, the forages chosen by farmers were essentially *C. brasiliensis, S. guianensis* Cook, *C. molle,* and *S. guianensis* 11995. The choices of fodders by farmers are generally identical with agronomic results. This observation has also been made here in South-Kivu on cassava-legumes intercropping system (Pypers et al., 2010).

5. Conclusion

In spite of the acidic soils, forages recommended were, *S. guianensis* 11995, *S. guianensis*

Cook, *C. molle* and *D. intortum*. The second step should be to adapt these forages in the farmers cropping systems. The seasons didn't influence in general the yield production. All the accessions of *V. unguiculata* and *C. ternatea* did not adapt anywhere and *C. brasiliensis* was sensitive to diseases and insects. Farmers participatory evaluation should be a good indicator for agronomists and also a way to early involve farmers in the innovations.

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