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Productivity and fodder potentials of groundnut in the Sudanian zone of Benin

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Abstract

Agronomic performance of groundnut differs according to variety. The objective of the study was to determine the productivity, the fodder and the nutritional potentials of haulms of four varieties of groundnut. A systematic randomized controlled trial was carried out with six replicates. Each block counted for has 24 plots with an area of 50 m². The plant material consisted of groundnut varieties TS 32-1, ICGV SM 85045, 69-101 and Moto Local, which were sown at six seeding densities. The best yield of fresh haulms was obtained with the variety 69-101 (16.76 t/ha), whereas the variety ICGV SM 85045 (9.26t/ha) had the lowest yield. The variety 69-101 had the highest yield in dry haul while Moto Local had the lowest. The best pod yield was obtained from 69-101 (6.28t/ha). The varieties 69-101 and ICGV SM 85045 had the highest NDF levels (Respectively 399.55 g/kg DM and 379.11 g/kg DM). Significant correlations were observed between fodder characteristics of the variety 69-101.It showed the most productive fodder potentials. Results on the nutritional quality of groundnut haulm were not significantly different. The characterization of these groundnut varieties will help pod producers and haulm users to achieve their production goals.

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Introduction

Groundnut (*Arachis hypogaea* L.) is an oilseed plant belonging to the family of Fabaceae (Priya *et al*., 2013). It is one of the most important oilseed crops grown around the world, particularly in the tropics and subtropics (Shiyam, 2010), i.e., in about 100 countries, including China, India, Nigeria, the United States, Indonesia and Sudan. Developing countries account for 96% of the world groundnut area and 92% of world production (Taru *et al*., 2010). In Benin it is used both for export and for local consumption (Didagbe *et al*., 2014).

Groundnut is mainly produced for edible oil (40-50%) and for direct consumption (Thirumala Rao *et al*., 2014). In addition, groundnut crops produce protein-rich haulms that are used in animal feed (Sahadeva Reddy *et al*., 2014). The seeds contain 40-50% fat, 20-50% protein and 10-20% carbohydrate (Onyuka *et al*., 2017).

In Benin, groundnuts cultivation is of great interest to producers because it is suitable good for crops rotation and does not require fertilizers. Different varieties of groundnut are produced and the yields in pod and haulms are controversial in the opinion of groundnut producers and farmers using its haulm (Moutouama, 2011). Similarly, survey of the typology of groundnut farmers in the Sudanian zone of Benin showed that several varieties are grown from one year to the next and producers do not cultivate the same varieties (Ahounou *et al*. 2016).

In this area, producers often use available seeds without considering their agronomic and fodder performances because of the poor structure of the sector and the limited supervision of producers on the implementation of technical itineraries. In the absence of agronomic data on groundnut varieties cultivated in the Sudanian zone of Benin, it is necessary to evaluate these varieties through an experimental study to characterize them for better value addition.

The objective of this study was to assess the productivity and fodder potential of four varieties of groundnuts (TS 32-1, ICGV SM 85045, 69-101, Moto Local) in the Sudanian zone of Benin. These varieties were selected because of their high use by groundnut producers and users of their haulms in this region (Moutouama, 2011).

Materials and methods

Study area

This study was carried out from June 2012 to October 2013 in the Northern Center for Agricultural Research (CRAN) one of the research centers of the National Institute of Agricultural Research of Benin (INRAB) based in Ina in the municipality of Bembéréké(Fig. 1).

This municipality is located between 09° 58' and 10° 40' North Latitude and between 02° 04' and 03° of East longitude and has an area of 3.348 km². The land is made of a vast plain and granito-genesy with undulating hills and mounts with North-South angular relief (Mont de Bembèrèkè) that makes the mountainous area of Borgou.

The climate is Sudano-Guinean type marked by a rainy season (May to October), a dry season (November to April) and the Harmattan (December to February). The annual rainfall is 1049.1 mm. The main potentialities of Bembérékéinclude agricultural resources (coton, maize, sorghum, yams, millet, groundnuts, etc.) and livestock resources (cattle, goats, sheep, and poultry) (Tokoudagba, 2014).

Experimental design

A complete randomized controlled trial test was carried out with six blocks, variety, harvesting stage and density being the studied factors. Each block, comprised 24 plots. One meter wide aisles separated the plots while 2m wide aisles separated the blocks. Each plot has an area of 50 m², 5m width and 10m length. Four groundnut cultivars (TS 32-1, ICGV SM 85045, 69-101, Moto Local) were sown at six seeding densities. The spacing of the plants used, which corresponds to the density of seedlings was of 50x20cm, 50x30cm, 60x20cm, 60x30cm, 70x20cm and 70x30cm.

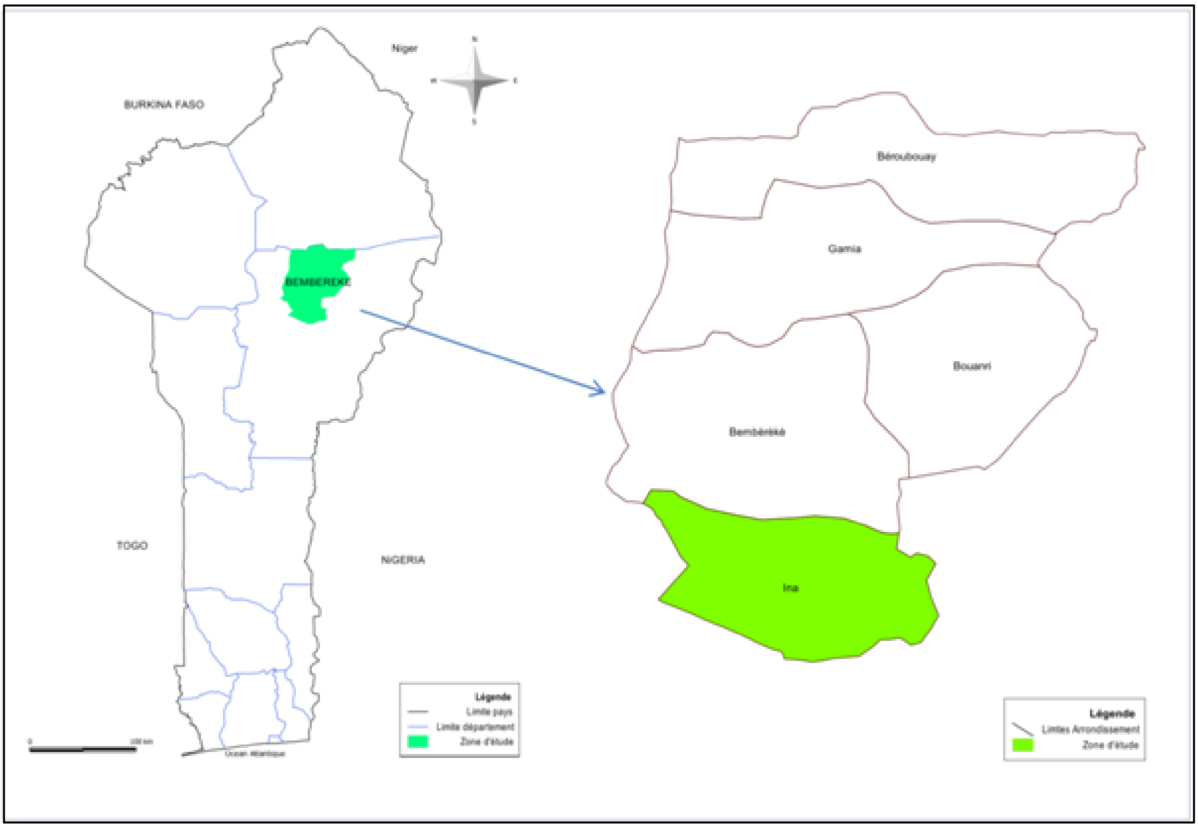


Fig. 1. Localization of the district of study in Benin.

The cultivars TS32-1, ICGV SM 85045 and Moto local have a vegetative cycle of 90 days and that of 69-101 is 120 days.

The field was treated with an herbicide (Kalach 360SL®). One week after the herbicide was employed the land was plowed to a depth of 15 cm. Then it underwent harrowing to prepare the seed bed. Plots were thereafter plotted and stitched prior to sowing. The seeding was done after a rain of at least 30 millimeters. Weeding was manually hoe and hand-done. The plots were cleaned twice, 21 and 35 days after sowing (DAS) for all cultivars.

Data collection

For the collection of data, two plots of 1m² each were selected randomly within each block. Harvesting was carried out in two stages: the first was done 15 days before the end of the cultivar cycle (75th DAS for TS32-1, ICGV SM 85045 and Moto local and 115th DAS for 69-101) and the second was done at the end of the vegetative cycles (90th DAS and 120th DAS).

The groundnut plants that were inside the plots were used for data collection. Measurements were based on the yields: fresh haulms, dry haulms, dry pod, dry stem and dry leaves. In addition to the agronomic parameters, haulm samples were taken from each groundnut cultivars to determine their content in ash, total nitrogen, crude fiber, ADF, NDF, ethereal extract, soluble fiber, calcium, phosphorus, potassium, sodium, magnesium, copper, iron, manganese, zinc, according to approved official methods (AOAC, 1990).

Statistical analysis

The data collected were entered in Excel and analyzed using SAS (Statistical Analysis System, 2006). The *Proc means* procedure was used for descriptive statistics. For the quantitative variables related to fodder characteristics and the chemical composition of groundnut, a single-factor ANOVA was used and the variety of groundnut haulm was the only source of variation. Indeed, the harvesting time (early and normal) and the seeding rate factors were not significant and were therefore not taken into account in the model.

The procedure *Proc GLM* was used for the analysis of variance and F test was used to determine the variety effect on the variables. Means were calculated and compared in pairs by the Student t test. Correlations between fodder characteristics variables were determined by variety of groundnut haulms using the Proccorr procedure of SAS. Principal Component Analysis (PCA) of Fodder Characteristics and Chemical Composition was performed for all varieties of groundnut haulms using the *Princompt* procedure of SAS (2006).

Results

Table 1shows the fodder characteristics of the four varieties of groundnut. They differed significantly. The best yield of fresh haulm was obtained with the variety 69-101 (16.76 t / ha) while ICGV SM 85045 (9.26t / ha) has the lowest one.

The variety 69-101 has the highest yield in dry haul while Moto Local showed the lowest one. For the haulm percentage of dry matter, ICGV SM 85045, TS32-1 and Moto Local have similar results, while 69-101 had the lowest value (30.5%). The best pod yield was given by 69-101 (6.28t / ha). This pod production was significantly different from that obtained for TS32-1 (4.99 t / ha) which was in second position (p <0.05). The pod yield of Moto Local (4.98 t / ha) and ICGV SM 85045 (4.18 t / ha) were similar.

Table 1. Fodder characteristics of four varieties of groundnut in the Sudanian zone of Benin.

Variables	69-101		ICGV SM 85045		Moto Local		TS32-1		Significance test
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Fresh haulm yield (t/ha)	16.76a	9.86	9.26c	4.66	10.12cb	4.97	11.12b	4.22	***
Dry haulm yield (t/ha)	4.44a	1.70	3.09c	1.64	2.84c	1.13	3.58b	1.40	***
Dry matter content in haulms (%)	30.45b	9.01	36.32a	14.5	32.76ab	14.33	34.66a	12.56	*
Pod yield (t/ha)	6.28a	3.33	4.18c	1.89	4.98b	2.32	4.99b	2.04	***
Dry leaf yield (t/ha)	1.56a	0.76	1.02bc	0.68	0.96c	0.51	1.16b	0.63	***
Dry stem yield (t/ha)	2.45a	1.06	1.59b	1.12	1.50b	0.73	1.71b	0.78	***

*: P<0.05 ; ***: P<0.001; means of the same row followed by the same letters do not differ significantly at 5%.
SD: Standard Deviation.

The dry leaf yield of 69-101 (1.56 t/ha) differs significantly from that of other varieties. The dry leaf yield of TS32-1 (1.16 t/ha) and ICGV SM85045 (1.02 t/ha) showed no significant difference (p> 0.05). The same trend was observed for ICGV SM 85045 and Moto Local (0.96 t/ha). However, the difference was significant between the dry leaf yield of TS32-1 and Moto Local (p <0.05). The dry root yield of 69-101 (2.45 t/ha) differed significantly from that ofthe other varieties. There were no significant differences between the dry stem yields of TS32-1 (1.71 t/ha), ICGV SM 85045 (1.59 t/ha) and Moto Local (1.50 t/ha).

Table 2. Correlation coefficients between fodder characteristics of the variety 69-101 (Above the diagonal)and the variety ICGV SM 85045 (Below the diagonal).

69-101 / ICGVSM 85045	RFF	RFS	TMSF	RG	RFeS	RTS
RFF	1	0.84 ***	-0.75 ***	0.92 ***	0.83 ***	0.78 ***
RFS	0.63 ***	1	-0.33 **	0.75 ***	0.65 ***	0.75 ***
TMSF	-0.42 ***	0.37 ***	1	-0.72 ***	-0.60 ***	-0.40 ***
RG	0.65 ***	0.20 NS	-0.48 ***	1	0.77 ***	0.78 **
RFeS	0.75 ***	0.38 ***	-0.42 ***	0.56 ***	1	0.68 ***
RTS	0.44 ***	0.55 ***	0.12 NS	0.19 NS	0.46 ***	1

RFF: fresh haulm yield; RFS: dry haulm yield; TMSF: dry matter content in haulms; RGS: pod yield; RFeS: dry leaf yield; RTS: dry stem yield; *: P<0.05; **: P<0.01; ***: P<0.001

Some correlations between fodder characteristics of groundnut varieties are presented in Table2 for69-101 and ICGV SM 85045 and Table 3 for Moto Local and TS32-1. The correlation coefficients between fodder characteristics of 69-101 were all significant (Table 2).

The dry matter in haulms (TMSF) was strongly (p <0.001) and negatively correlated with fresh haulm yield, pod yield, dry leaf yield and the dry stem yield. It was moderately correlated with the dry haulm yield (p <0.01). The correlation between pod yield and dry haulm yield was positive and strong (p <0.001).

Table 3. Correlation coefficients between groundnut fodder characteristics of the variety Moto Local (Above the diagonal)and the variety TS32-1 (Below the diagonal).

Moto Local	RFF	RFS	TMSF	RG	RFeS	RTS
TS32-1						
RFF	1	0.53 ***	-0.67 ***	0.82 ***	0.73 ***	0.32 ***
RFS	0.56 ***	1	0.15 NS	0.34 ***	0.27 *	0.59 ***
TMSF	-0.53 ***	0.32 **	1	-0.57 ***	-0.41 ***	0.24 *
RG	0.73 ***	0.17 NS	-0.55 ***	1	0.71 ***	0.47 ***
RFeS	0.58 ***	0.22 NS	-0.33 **	0.62 ***	1	0.44 ***
RTS	0.16 NS	0.47 ***	0.31 **	0.19 NS	0.26 *	1

RFF : fresh haulm yield ; RFS : dry haulm yield ; TMSF : dry matter content in haulms ; RGS : pod yield ; RFeS : dry leaf yield ; RTS : dry stem yield ; * : P<0.05 ; ** : P<0.01 ; *** : P<0.001.

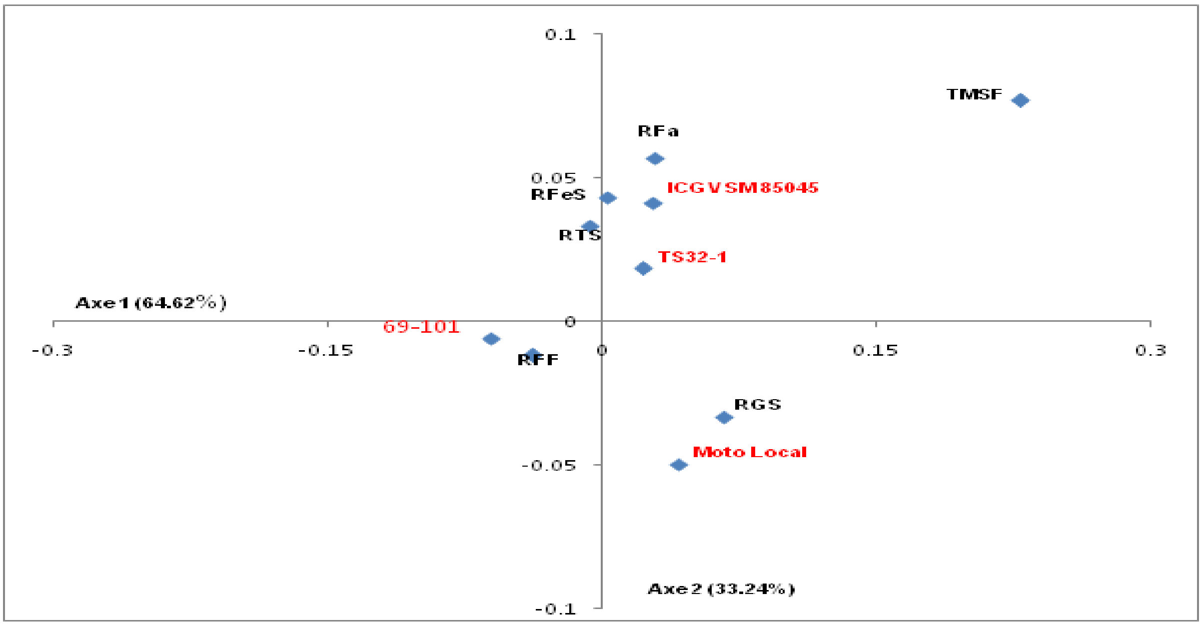
Correlations between pod yield and dry haul yield, pod yield and dry-stem yield, dry-stem yield and dry matter in haulms were not significant for ICGV SM 85045 (Table 2). The correlation coefficient was negative and moderate between dry matter content in haulm and fresh haulm yield and between pod yield and dry leaf yield. For Moto local, other correlations were significant (Table 3), but from the correlation between the dry matter content in haulms and dry haulm yield. The correlation was negative and strong (p <0.001) between dry matter content of haulms and fresh haulm yield, pod yield and dry leaf yield. The correlation between pod yield and dry haul yield was positive and high (p <0.001).For TS32-1the correlation between dry haulm yield and pod yield was not significant (p> 0.05. The correlation between pod yield and dry leaf yield was high and significant (p <0.001). The correlations between dry matter content and fresh haulmyield, pod yield and dry leaf yield were negative and significant.

Table 4. Chemical composition of four groundnut fodder in the Sudanian zone of Benin.

Variables	69-101		ICGV85045		Moto local		TS32-1		Significance test
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Ash (g/kg)	122a	3.46	121.5a	5.80	123.75a	8.96	133.5a	7.94	NS
Total Nitrogen (g/kg)	201.25a	11.79	208.75a	15.75	195a	10.80	201a	9.20	NS
Crude fiber (g/kg)	203.00a	16.20	200.25a	23.65	202.25a	7.80	199.25a	7.13	NS
ADF (g/kg)	280.62	25.34	293.18a	20.18	282.63a	8.97	278.41a	9.60	NS
NDF (g/kg)	399.55a	15.43	379.11ab	12.49	369.05bc	19.00	341.81c	27.96	***
Ethere extract (g/kg)	22.48a	2.14	18.36a	2.15	21.27a	4.95	19.66a	0.95	NS
Solublefiber (g/kg)	118.93a	10.41	85.92 b	21.67	86.42ab	27.87	63.39b	22.03	*
Calcium (g/kg)	16.02a	0.56	14.72a	0.49	14.75a	1.54	15.67a	0.57	NS
Phosphorus (g/kg)	2.12a	0.17	2.22a	0.09	2.17a	0.12	2.3a	0.24	NS
Potassium (g/kg)	34.65a	1.40	32.17ab	1.92	27.57c	2.50	30.25b	1.65	**
Sodium (g/kg)	0.7a	0.93	0.37a	0.38	0.1a	0.00	0.32a	0.20	NS
Magnesium (g/kg)	4.4a	0.35	4.35a	0.40	4.42a	0.15	4.35a	0.10	NS
Copper (mg/kg)	13.45a	3.90	14.12a	4.40	13.9a	3.74	17.62a	1.74	NS
Iron (mg/kg)	314.75a	49.60	372.5a	51.93	394.45a	214.76	393.25a	15.06	NS
Manganese (mg/kg)	139.3a	34.50	152.5a	19.09	131.37a	26.26	160.85a	3.28	NS
Zinc (mg/kg)	38.25a	5.25	42.5a	7.50	45.75a	9.67	51.33a	2.08	NS

NS : P>0.05 ; * : P<0.05 ; ** : P<0.01 ; *** : P<0.001.Means of the same row followed by the same letters do not differ significantly at 5%; SD: Standard Deviation.

The principal component analysis of the fodder potential and the pod yield was used to distinguish the four varieties of groundnuts through their production performances (Fig. 2). The first factor axis accounts for 64.62% of the variation. On this axis, 69-101 was characterized by the yield of fresh haulm and opposed to TS32-1 and to a lower extent to Moto Local, which correlated with the pod yield. The second axis accounts for 33.44% of the variation and oppose Moto Local with ICGV SM 85045 to a lesser extent withTS32-1. TS32-1 and ICGV SM 85045 were characterized by higher yields of dry leaves and stems. Nevertheless, their dry haulm yield was more related to ICGV SM 85045.



RFF : RFF : fresh haulm yield ; RFS : dry haulm yield ; TMSF : dry matter content in haulms ; RGS : pod yield ; RFeS : dry leaf yield ; RTS : dry stem yield.

Fig. 2. Principal component analysis of the characteristics of four groundnut varieties in the Sudanian zone of Benin.

The chemical composition of the four varieties of groundnuts shown in Table 4. The levels of NDF and soluble fiber differed significantly according to the groundnut varieties: 69-101 and ICGV SM 85045 had the highest levels of NDF. Moto Local had an NDF content which differed significantly from that of 69-101 but not from that of ICGV SM 85045, while TS32-1 had the lowest NDF content.

The varieties 69-101 and Moto Local had the highest soluble fiber levels with 118 and 86.4 g/kg DM, respectively. The soluble fiber contents of ICGV SM 85045 and of TS32-1 did not differ significantly and were respectively 85.9 and 63.4 g/kg DM. The contents in crude protein, crude fiber, ADF and ethereal extract did not differ significantly according to the groundnut varieties.

No significant difference was observed between the contents in the soluble minerals and the trace elements of the groundnut varieties.

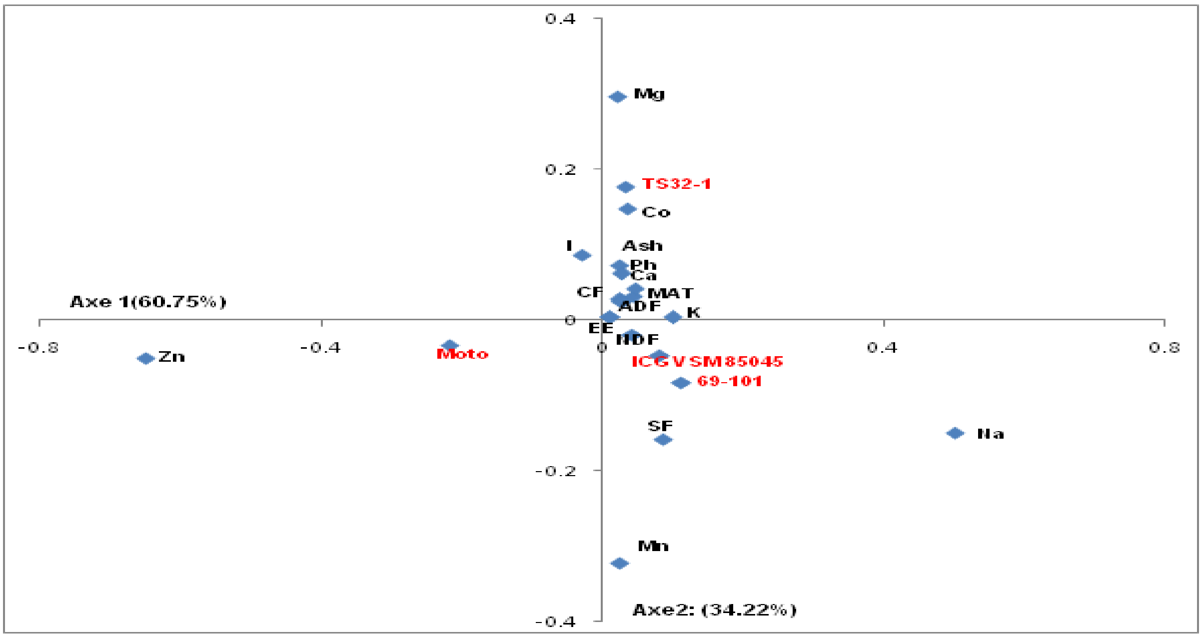
The main component analysis of the dietary values, soluble minerals and trace elements of the four groundnut varieties is shown in Fig. 3. The first axis explained 60.75% of the variation and contrasted Moto Local with the others Varieties (TS32-1, ICGV SM 5045 and 69-101). Moto Local was characterized by its zinc content.

The second axis explained 34.22% of the variation and contrasted TS32-1 with ICGV SM 85045 and 69-101. On this axis TS32-1 was characterized by its Copper and Magnesium content. The other variables do not characterize other varieties.

Discussion

The analysis of variance revealed very significant differences between fodder characteristics of the four varieties of groundnut. The yield of haulm (fresh and dry), pod, dry leaf and dry stem of the different varieties show that the variety 69-101 was more productive, by opposition to ICGV SM 85045 for fresh haulm and pod yield, and Moto Local for dry haulm, dry leaf and dry stem yield.

The differences observed in relation to the fodder characteristics of the four varieties of groundnut can be explained by the expression of their genetic potential. Gaufichon *et al.* (2010) mentioned that gene expression can be modified depending on environmental conditions. The results obtained by Goalbaye *et al.* (2016) in Chad and Betdogo *et al.* (2015) in Cameroon relative to dry haulm yield are lower than those obtained in our experiment.



Co: Copper; Zn: Zinc; Mn: Manganese; SF: Soluble fiber; Mg: Magnesium; Na: Soduim; EE: Ethere Extract; CF: Crude Fiber; I: Iron; Ph: Phosphorus; Ca: Calcuim; NDF Neutral Detergent Fiber; ADF: Acide Detergent Fiber; MAT: Total Nitrogen

Fig. 3. Principal component analysis of the chemical composition of the four varieties of groundnut.

These differences are related to the production performance of the varieties they have used but also to the nutrient richness of the soil. The pod yields in our study ranged from 6.28 to 4.18 tons/ha. Our results also are higher than those obtained by Gunri *et al.* (2015) in the Western Bengal region of India and Bano *et al.* (2016) in Pakistan. The best pod yield was obtained with the strain 69-101 which is a slow grower. This confirms the effect of maturity on the pod yield. According to Coulibaly *et al.* (2017), poor yields generally are linked to varieties with early maturity compared to varieties with delayed maturity.

Correlation analysis revealed that the pod yield was strongly, positively and significantly related to the dry haulm yield for 69-101. However, for the other varieties, it was low and significant for Moto Local and not significant for the ICGV SM 85045 and TS32-1. The same trend was observed for yields of leaf and stem. Therefore, taking into account the correlations, the importance of these characteristics on the evolution of the pod yield of these varieties is emphasized. In the context of a selection, it will be necessary to take into account those characteristics which are interdependent and have a strong association. Barariyal and Dobariya (2012) also came to the same conclusion. Any decline in haul productivity will result in reduced pod yield for 69-101. On the other hand, for the three other varieties, the effect will be less pronounced. In our study, 69-101 can be considered the most productive.

For the principal component analysis of fodder characteristics of the groundnut varieties, all parameters except dry matter were used to distinguish groundnut varieties. Each variety is characterized by one or more fodder characteristics. For the implementation of a selection program, the results of the main component analysis also should be taken into account.

The results of the nutritional quality of groundnut haulms of the experiment did not present much significant differences. The ash contents were high (121 to 124 g/kg DM) but do not show any significant difference. Similar values were obtained by Sahadeva Reddy *et al.* (2014) for other groundnut varieties in Andhra Pradesh State.

This result shows that the nature of the maturation has no effect on the ash content. This is contrary to observation made by Sahadeva Reddy *et al.* (2014). According to these authors, the ash content is low for varieties with early maturity and high for those with delayed maturity. However, Ayantunde *et al.* (2014) obtained lower ash contents on unspecified varieties. The four varieties used for experimentation recorded crude protein contents ranging from 199 to 203 g/kg DM.

These values are higher than those obtained in Ibadan State of Nigeria by Etela and Dung, (2011) on the varieties such as: M170-80I, M554-76, M572-80I, RMP-12, UGA-2 and UGA-5. This difference could be attributed to a higher level of leaf and groundnut stem in our sample compared to those of other authors as evidenced by the low NDF and ADF values of our study.

The highest levels of NDF and ADF obtained in our study were generated by 69-101. These values are much lower than those obtained by Etela and Dung. (2011) in Ibadan State, Nigeria, on varieties M170-80I, M554-76, M572-80I, RMP-12, UGA-2 and UGA-5 and by Ayantunde *et al.* (2014) in the city of Bamako in Mali on unspecified varieties.

Conclusion

The determination of productivity, fodder and nutritional potential of four varieties of groundnut sin the Sudanian zone of Benin revealed a number of features.

The late maturing variety 69-101 was the most productive for all parameters, the variety ICGV SM 85045 produced less pods and the Moto Local less aerial parts. Any reduction in haulm productivity results in a lower pod yield for 69-101.

On the other hand, for the three other varieties, a decline in haulm yield does not influence the yield of pods. The nutritional quality of the haulms of the four varieties of groundnut varied little. These groundnut thaulms have good nutritional quality for ruminants and can be used to meet their nutrient requirements. However, some experimentations on the digestibility of these varieties are required to evaluate the quality of the valorization of groundnut haulms in animals feeding.

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