Optimization of forage yield using improved dual-purpose sorghum (*Sorghum bicolor*) and groundnut (*Arachis hypogaea*) varieties

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Abstract
Feed deficit is a major constraint on animal production in Burkina Faso. To remedy this, the intensive production of high-quality fodder is an alternative. In this context, the present study was conducted to improve the supply of high-quality fodder for livestock feed. The study took place in INERA Saria experimental station in Burkina Faso. A completely randomized Fischer block with four (04) replicates trial was conducted with eight (08) treatments involving two (02) varieties of sorghum (Ponta Negra and Sariaso 16), two (02) varieties of groundnut (ICGV 01276 and SH 67A). The parameters evaluated were grain and forage yields, nutritional value of the forage, and the effect of the association on weed management. The results indicated that in both monoculture and association, the highest grain yields were obtained with the sorghum variety Sariaso 16 (4343 kg/ha) and the groundnuts variety ICGV 01276 variety (2143 kg/ha) for. The highest forage yields were observed on Ponta Negra (8730 kg/ha) and ICGV 01276 (4038 kg/ha). Except for the grain yield of Ponta Negra, ICGV 01276 and the forage yield of Sariaso 16-ICGV 01276, all treatments association showed gains in productivity. No significant differences were observed for nutritional values of the fodder between the sorghum varieties, but their values were significantly lower for most of the groundnut leaf. Intercropping produced better results in terms of biomass than monoculture. The results obtained show that the varieties and crop association used have great potential for improving the supply of fodder for livestock feed.

Keywords: Dual-purpose varieties; Forage; Groundnut; Intercropping; Sorghum.

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Optimisation de la production fourragère à base de variétés améliorées de sorgho (*Sorghum bicolor* [l.] Moench) et d'arachide (*Arachis hypogaea* [l.] Cult) à double usage.

Résumé

Le déficit alimentaire du bétail est une contrainte majeure de la production animale au Burkina Faso. Pour y remédier, la production intensive du fourrage de qualité se présente comme une alternative. C'est dans ce contexte que la présente étude a été menée avec pour objectif de contribuer à améliorer l'offre fourragère de qualité pour l'alimentation du bétail. Elle a été conduite dans la station expérimentale de l'INERA Saria, dans la région de Nando au Burkina Faso. Un essai en blocs de Fischer complètement randomisé comportant huit (08) traitements avec deux (02) variétés de sorgho (*Ponta Negra* et *Sariaso 16*) et de deux (02) variétés d'arachide (*ICGV 01276 et SH 67A*) et quatre (04) répétitions par traitement.

Les paramètres évalués sont les rendements en grains et fourrage, la valeur nutritive du fourrage et l'effet de l'association sur la gestion des mauvaises herbes. Les résultats indiquent qu'en monoculture comme en association, les rendements en grains les plus élevés ont été obtenus avec la variété Sariaso 16 (4343kg/ha) pour le sorgho et la variété ICGV 01276 (2143kg/ha) pour l'arachide. Les rendements en fourrage les plus élevés ont été observés avec Ponta Negra (8730kg/ha) et ICGV 01276 (4038kg/ha). A l'exception du rendement en grains de Ponta Negra, de l'ICGV 01276 et celui en fourrage de Sariaso 16-ICGV 01276, tous les traitements en association indiquent un gain de productivité et d'espace. Aucune différence significative n'a été observée pour les valeurs nutritives des fourrages entre les variétés de sorgho, cependant leur valeur est significativement inférieure pour la plupart des paramètres des fanes d'arachide. L'association culturale n'a pas eu d'effet sur la densité des mauvaises herbes, mais a présenté de meilleurs résultats sur leur biomasse par rapport à la monoculture. Les résultats obtenus montrent que les variétés et l'association culturale utilisées ont un grand potentiel pour l'amélioration l'offre fourragère pour l'alimentation du bétail.

Mots clés : association culturale, fourrage ; variétés à double usage, arachide et sorgho.

Introduction

Ruminant farming in Burkina Faso faces several challenges, including food shortages that limit production. Indeed, this type of farming is dominated by extensive systems, particularly pastoral and agropastoral, in which natural pastures constitute the bulk of the animals' diet. In addition, natural pastures are deteriorating both qualitatively and quantitatively every year. This deterioration is due to several factors including climate, soil, demography, and anthropogeny, as well as the expansion of the agricultural frontier (KIEMA et al., 2008; ZAMPALIGRÉ et al., 2013). Natural rangelands are gradually shrinking at a rate of 105,000–250,000 ha/year owing to anthropogenic factors (RICHARD et al., 2019). Between 1975 and 2013, the area covered by rain-fed agriculture in Burkina Faso increased from 15% to 39%, representing an overall increase of 160% at the expense of pastoral and protected areas (TAPPAN et al., 2016; GONIN, 2017). This deficit ranges from 35 to 70% for dry matter and from 40 to 80% for Crude Protein (Kéré, 2006), which negatively impacts ruminant productivity (TAMINI et al., 2014).

Strengthening the interactions between agriculture and livestock farming through their integration remains a major strategy for improving crop and livestock production in Burkina Faso (TOÉ et al., 2022). Cultural residues (straw and haulms) are essential components of livestock feed in pastoral and agropastoral systems (OUATTARA et al., 2024). Consequently, research has been conducted to develop and integrate dual-purpose varieties into food production systems (ZORMA, 2017). These selected varieties improve fodder and grain production. The use of improved dual-purpose varieties adapted to agro-ecological zones according to cropping systems is a promising alternative (SANGARÉ et al., 2005). It is with this in mind that the present study was conducted, with the overall objective of contributing to the improvement of the supply of quality fodder for livestock feed in Burkina Faso.

I. Materials and methods

I.1. Study area

The study was conducted in the North Sudanese agro-ecological zone of Burkina Faso at the experimental research station of the Regional Center for Environmental and Agricultural Research of INERA in Saria (Figure 1). This research station is located at 23 km east of Koudougou at 80 km northwest of Ouagadougou, between 12°16' north latitude and 2°09' west longitude at an altitude of 300 m. The climate of the area is North Sudanese (ZAMPALIGRÉ *et al.,* 2021; SANFO et al., 2023b), subject to interannual variations and characterized by two seasons: a rainy season from May to October, and a dry season from November to April. Rainfall is characterized by heavy and irregular rain at the beginning and end of the rainy seasons. It is subject to significant spatial and temporal variations, resulting in water deficits that are detrimental to agricultural production.

The average annual rainfall at the station varies from 700 to 900 mm. The soils of Saria are leached tropical ferruginous soils derived from granitic bedrock. They have upper horizons with a silty-sandy to sandyclayey texture and a continuous massive structure. Similar to most tropical ferruginous soils (approximately 39% of soils in Burkina Faso), the soils of Saria are characterized by a deficiency in nitrogen and phosphorus and a low organic matter (OM) content, which explains their low cation exchange capacity (CEC) and slight acidity (Traoré, 2012).

The vegetation in Saria is characterized by the presence of savannah with annual grasses, trees, and shrubs (ZAMPALIGRÉ et al., 2013). Currently, this vegetation is disappearing owing to strong demographic and anthropogenic pressures and climate change. The vegetation in the village of Saria is dominated by the following species: *Parkia biglobosa* (Jacq.) R.Br., *Vitellaria paradoxa* C.F.Gaertn., *Adansonia digitata* L., *Lannea microcarpa* Engl.et K. Krause, *Tamarindus indica* L., *Kaya senegalensis* (Desv.), *Faidherbia albida* Del. (SEHOUBO et al., 2023).

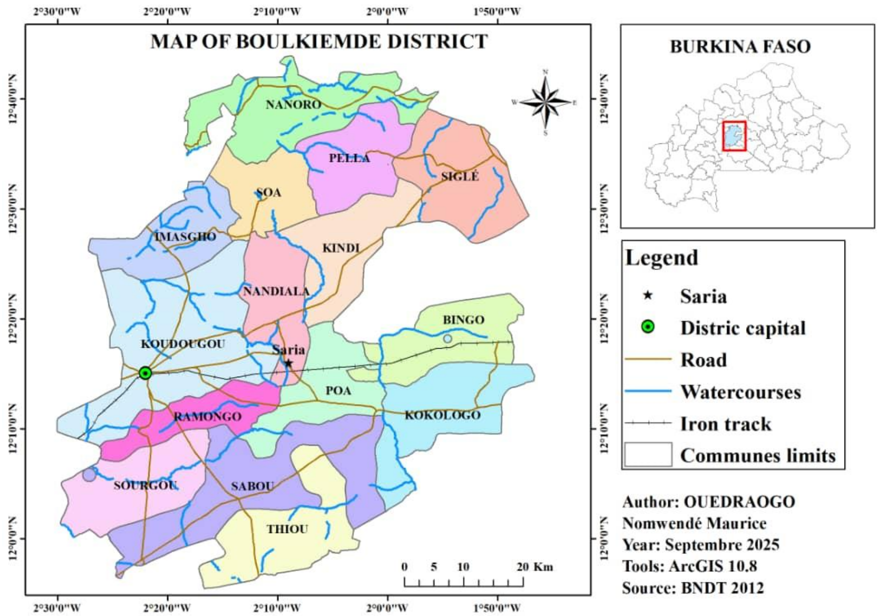

Figure 1 : Study area

I.2. Plant materials

The plant material was selected with regard of popular cereal and legume crops that dominate the northern Sudanese zone. These include two varieties of sorghum and two varieties of groundnuts. The selected varieties are improved dual-purpose varieties that are early to semiearly maturing and drought- tolerant. The selected varieties were obtained from INERA (Sariasso 16 and SH 67A), IPA (Ponta Negra), and ITRA (ICGV 01276). The varieties used and their characteristics are listed in Table I.

Table I. List of dual-purpose species and their varieties.

Speculatio ns	Species	Cultivar	Grain yield (t/ha)	Biomass (t DM/ha)
Sorghum	*Sorghum bicolor* L Moensh	Ponta Negra	0.4 - 3 t/ha	5.3 – 10 t/ha
		Sariasso 16	2-3,4 t/ha	4,1 t/ha
Groundnut	*Arachis hypogaea* L.	ICGV 01276		
		SH 67A	2 t/ha	

I.3. Experimental *design*

The experimental design was a completely randomized Fisher block trial with four (04) replicates. The experiment consisted of eight (08) treatments with two (02) varieties of sorghum (Ponta Negra and Sariasso 16) and two (02) varieties of groundnut (ICGV 01276 and SH 67A). The size of the elementary plots was 35 m² (7 m × 5 m), separated by 1 m between them and 1 m between blocks.

The eight treatments were as follows: (T1) Ponta Negra sorghum only, (T2) Sariasso16 only, (T3) ICGV 1276 groundnut only, (T4) SH 67A only, (T5) Ponta Negra and ICGV 01276 in combination, (T6) Ponta Negra and SH 67A in combination, (T7) Sariasso16 and ICGV 1276 in combination, and (T8) Sariasso16 and SH 67A in combination.

I.4. Trial conduction an crop management

The trial began with the soil which previous crop was cowpea preparation. Plowing was performed on moist soil (10/07/2019) using a tractor, followed by staking and labelling to mark the individual plots. Sowing was carried out manually in rows using a pickaxe on 17/07/2019 for sorghum and a week later for groundnuts (24/07/2019). Groundnut sowing was staggered

by 7 days from sorghum sowing to allow sorghum to draw on the nitrogen available in the soil

for its nitrogen nutrition and thus avoid competition with groundnuts for this resource. Each basic plot consisted of nine (09) rows with a density of two plants per hole for sorghum and one plant per hole for groundnuts. Thinning and transplanting were performed 15 days after sowing (DAS) to achieve the desired sowing density. The combination type was an intercalated combination with two (02) rows of sorghum for one (01) row of groundnut. Spacing was 60 cm between rows and 40 cm between plants within rows for all cultivars. The fertilization of the trial consisted of NPK fertilizer (14- 23-14) and was applied at a rate of 100 kg/ha 20 days after sowing. The fertilizer was broadcast onto furrows opened with a pickaxe a few centimeters (cm) from each seed row. In addition, sorghum in monoculture and in association received 50 kg/ha of urea at 50 days after sowing (05/09/2019), followed by ridging to ensure good plant stability to ensure better use of water. Each plot was manually hoed twice at 20 days after sowing and 30 days after sowing to control weeds.

To effectively control pests all plots were treated with Viper (Acetamiprid 16 g/l + Indoxacarb 30 g/l) at a dose of one (01) litre per hectare (1 l/ha) at the start of flowering and fruiting. A second treatment with K-optimal (Lambda-cyhalothrin 15 g/l + Acetamiprid 20 g/l) was applied at the onset of the first symptoms of fall armyworm infestation.

I.5. Data collection

Grain yield and fodder biomass evaluation

Grain yield and fodder biomass was assessed at the time of harvesting the sorghum grains and groundnut pods. It was carried out on three yield squares (1 m²) along the diagonals of each elementary plot. Sorghum panicles and groundnut pods were harvested separately and dried under sun for 10 days before being threshed/shelled and winnowed. The grains obtained were further dried under the sun until they reached a constant weight and then weighed using digital scales (5 kg ± 1 g). The averages of yield were calculated, and then to the hectare (ha) using the following formula:

$$GY = Dry\ grain/seed\ weight\ ((Kg.m^{-2}) X\ 10000\ m^2$$

Where GY = *grain yield (kg/ha)*

The fodder biomass (FB) was measured in three yield squares along the diagonal of each usable plot after harvesting the panicles and pods. The fresh weight of the forage in each yield square (1 m²) were measured. Then, a 500 g sample of forage were collected from each yield square per plot and dried in an oven at 105°C for 24 h to determine the dry matter (DM) using the following formula:

$$\text{FB}\left(\frac{\text{Kg}}{\text{ha}}\right) = \frac{\text{FM (Kg)} \times \text{DM(kg)}}{(\text{SW (Kg)} \times 10000\ \text{m}^2)}$$

With FB = fodder biomass (kg), FM= fresh matter (Kg), DM= dry matter (Kg), and SW=sample weight (Kg).

Intercropping efficiency assessment

For intercropping efficiency assessment, the following parameters were collected : the equivalent area ratio (EAR), the effect of the combination on weed control and the secondary crop productivity index (SCPI).

The association in terms of yield was assessed using EAR, which is defined as the area of land under pure cultivation required to produce the yields achieved per hectare of associated crops (N'goran et al., 2011) using the following formula:

$$\text{EAR} = \sum_{n=1}^{N} YN/SN$$

Avec $Y_1 + Y_2 + \ldots + Y_N$ = *Yield of each component in the intercropping system*

$S_1 + S_2 + \ldots + S_N$ = *Yield of each component in monoculture*

Weed control was recorded 75 days after sowing to determine the effects of the different treatments on weed density. A yield square (1 m^2) was used and placed three times in each elementary plot along the diagonal, and the weeds inside were counted (Ekeleme *et al.,* 2019; Sanfo *et al.,* 2023). The averages values were then calculated. Weeds were then collected and weighed. The samples were dried in an oven at 105°C for 48 h to obtain data on the dry biomass of the weeds (kg DM/ha) using the following formula:

$$WB\left(\frac{Kg}{ha}\right) = \frac{FM\ (Kg) \times DM\ (Kg)}{SW\ (Kg) \times 10000\ m^2}$$

Where *WB=Weed Biomass*, *FM =fresh matter (kg), DM = dry matter, and SW=sample weight*

SCPI is the standardization of secondary crop (groundnut) yields in relation to those of the main crop (sorghum) in combination, according to the following formula (KHAN et al., 2020, SANFO et al., 2023b):

$$\text{SCPI} = \left(\frac{SY}{GY}\right) * Yg + Ys$$

Where *SY and GY* are *the average yields of sorghum and groundnuts in monoculture, respectively. Ys and Yg are the average yields of sorghum and groundnut combinations, respectively.*

Sorghum straw and groundnut haulm nutritive value

In order to determine the nutritional value of the forage, samples of approximately 500 g were taken from each sorghum elementary plot, pre-wilted under sun light, and then dried under shade for 21 days to prevent denaturation of the bromatological value of the forage. The samples were subjected to chemical composition analyses. Near-infrared (NIRS) method were used to analyze these forages at the NIRS-INERA-ILRI Laboratory. The following parameters were then determined:

crude protein (CP), ash, Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Acid Detergent Lignin (ADL), metabolizable energy, and *in vitro* organic matter digestibility (IVOMD).

I.6. Data analysis

Microsoft Excel 2013 was used for data entry and to create tables and graphs. Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 20.0 software, for analyses of variance (ANOVA) and means comparition using Fisher's test (LSD) at 5% significance level of when ANOVA were significant.

II. Resultats

II.1. Grain yield and fodder biomass improvement

The grain and forage yields of the two varieties of sorghum and groundnuts in monoculture were higher than those of the combinations (Table II). Furthermore, the grain yield of the sorghum variety Sariasso16 variety was higher than that of the variety Ponta Negra variety in both monoculture and combination cultivation. In terms of forage biomass, the sorghum variety Ponta Negra yielded the best results (Table II). For groundnut, ICGV 01276 yielded higher in terms of grain and forage than the variety SH 67A in both pure and mixed cropping systems. Analysis of variance revealed presence of significant differences for all the parameters studied.

Table II : Sorghum and groundnut grain yield and fodder biomass regarding the interaction between cropping systems and cultivars

Treatments	Sorghum Grain yield (kg /ha)	Sorghum fodder biomass (kgDM /ha)	Groundnut Grain yield (kg /ha)	Groundnut Fodder biomass (kgDM/ha)
Ponta Negra	3084^{b}±517	8730^{a}±1988	-	-
Sariasso16	4343^{a}±1342	4910^{bc}±1906	-	-
ICGV 01276	-	-	2143^{a}±458	4038^{a}±751
SH 67A	-	-	1437^{b}±700	2376^{b}±965
Ponta Negra-ICGV	1888^{c}±549	5722^{b}±1259	680^{c}±111	1562^{bc}±364
Ponta Negra-SH67A	1822^{d} ±674	6285^{b}±1184	648^{c}±403	1422^{bc}±964
Sariasso 16-ICGV	2999^{bc} ±818	2567^{bc}±937	842^{c}±222	1606^{bc}±801
Sariasso 16-SH67A	2783^{bc} ±377	2476^{c}±1068	595^{c}±182	1185^{c}±305
F	15,343	30,12	24,396	22,76
P-Value	0,00	0,00	0,00	0,00
Signification	HS	HS	HS	HS

NB: Numbers in the same column marked with the same letter are not significantly different at the 5% probability threshold. Key: HS = highly significant

II.2. Sorghum and cowpea intercrop improves grain and fodder biomass yield

The equivalent area ratios (EAR) in grains of the combined cropping systems varied from 0.93 (Ponta Negra:ICGV 01276) to 1.08 (Sariasso 16:ICGV 01276). These results indicate a productivity gain ranging from 4 to 8% compared to monoculture, representing a similar space saving (Table III). However, a 7% reduction compared to monoculture was observed with the Ponta Negra and ICGV 1276 combination. Combinations involving the Sariaso16 variety yielded the best results compared to those with Ponta Negra. Overall, the crop combinations increased the grain yield potential of the varieties used. With regard to forage, total EAR values were higher than 1 for combinations with Ponta Negra, while they ranged from 0.94 to 1 for combinations of Sariasso 16 with. intercroping involving Ponta Negra produced the highest forage yields, with yield gains ranging from 5% to 32%, corresponding to a similar level of land-use efficiency. In contrast, the two groundnut varieties intercropped with Sariasso 16 resulted in a reduction of total forage biomass by 0–8% compared than in monoculture.

Table III : Evaluation of the combination in terms of biomass and grain yield

Cropping system	EAR		SCPI	
	Grain yield	Fodder biomass	Grain yield	Fodder biomass
Monoculture Ponta Negra	1,00	1,00	3084,17	8730,08
Monoculture Sariasso 16	1,00	1,00	4343,33	4909,91
Monoculture ICGV	1,00	1,00	2143,33	4037,74
Monoculture SH 67A	1,00	1,00	1437,27	2375,72
IntercroppingPonta Negra-ICGV	0,93	1,05	2866,27	9098,27
Intercropping Ponta Negra-SH	1,04	1,32	3213,49	11510,51
Intercropping Sariasso 16-ICGV	1,08	0,92	4706,03	4519,07
Intercropping Sariasso 16-SH	1,05	1,00	4580,97	4925,47

EAR= equivalent area rate; SCPI= secondary crop productivity index

In general, the secondary crop productivity index (SCPI) values for the associated cropping systems were higher than those of the pure sorghum variety (Table III). Ponta Negra in association gave the highest SCPI in fodder (9098.27 and 11510.51), while in grain, the association including Sariasso16 (4706.03 and 4580.97) gave the best SCPI.

II.3. Weeds density

In terms of weed density, sorghum monoculture reduced the number of weeds compared with groundnut monoculture. The sorghum variety Ponta Negra was the most competitive, whereas no significant difference was observed between Sariasso 16 and the two groundnut varieties. Overall, the sorghum-groundnut crop combination did not reduce weed density and coverage (Table IV). Analysis of variance revealed a highly significant difference ($p= 0.015$) in weed density at the 5% threshold.

With regard to weed biomass, in pure cultivation, the sorghum varieties had the lowest weed biomass. However, the amount of weed biomass was higher in monoculture than in the combination treatment. Analysis of variance revealed a significant difference (p<0.000) in weed biomass among the different treatments.

Table IV: Effect of intercropping on weeds

Cropping system	Weeds density (nb/m²)	Weeds biomass (Kg DM/ha)
Monoculture Ponta Negra	25,50[a] ± 21,5	27,50[bc] ± 24,73
Monoculture Sariasso 16	71,83[ab]± 31,75	200,49[b] ± 134,60
Monoculture ICGV 01276	43,50[ab] ± 32,19	214,17[b] ± 127,77
Monoculture SH 67A	73,64[ab] ± 50,67	486,98[a] ± 426,14
Intercropping Ponta Negra-ICGV 01276	53,18[ab] ± 35,88	133,53[b] ± 142,08
Intercropping Ponta Negra-SH 67A	48,64[ab] ± 31,20	271,88[b] ± 206,21
Intercropping Sariasso16- CGV 01276	77,40[b] ± 59,67	196,04[b] ± 229,52
Intercropping Sariasso16-SH 67A	69,00[ab] ± 30,75	324,17[ab] ± 238,21
F	2,664	4,56
P-Value	0,015	0,000
Signification	HS	VS

NB: Numbers in the same column marked with the same letter are not significantly different at the 5% probability threshold (LSD).
Key: VS = very significantly ; HS = highly significant

II.4. Sorghum and groundnut nutritive value as fodder

The analysis revealed low CP contents (Table V) ranging from 3.96% to 5.04% respectively for Sariasso 16 and Ponta Negra, and high NDF (68.4% for Sariasso 16 and 70.58% for Ponta Negra) and ADF (39.60% for Sariasso 16 and 39.25% for Ponta Negra) contents. ANOVA did not reveal the presence of any significant differences between the two sorghum varieties in terms of the chemical composition of the forage for any of the elements.

Table V : Nutritive value of fodder (in % DM)

Crop species	Sorghum					Groundnut				
Cultivar	Ponta Negra	Sariasso 16	*F*	*P-Value*	Signification	ICGV 01276	SH 67A	*F*	*p-value*	Signification
DM (%)	91,95	91,58	*1,447*	*0,274*	NS	91,82	91,73	*0,519*	*0,498*	NS
Ash (%)	9,28	9,77	*0,751*	*0,42*	NS	11,9	11,46	*0,718*	*0,429*	NS
CP (%)	5,04	3,96	*4,189*	*0,087*	NS	14,05	16,28	*20,858*	*0,004*	HS
NDF (%)	70,58	68,4	*0,887*	*0,383*	NS	50,26	44,12	*41,064*	*0,001*	HS
ADF (%)	39,25	39,6	*0,038*	*0,851*	NS	40,13	34,36	*16,434*	*0,007*	HS
ADL (%)	4,24	4,22	*0,004*	*0,95*	NS	7,96	6,88	*16,412*	*0,007*	HS
ME (%)	7,08	7,2	*0,102*	*0,76*	NS	7,58	7,98	*22,18*	*0,003*	HS
IVOMD (%)	48,79	49,33	*0,061*	*0,813*	NS	55,25	57,88	*17,882*	*0,006*	HS

Note. DM = dry matter, CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber, ME = metabolizable energy, IVOMD = *in vitro* organic matter digestibility er. NS = Not significant at $p \leq .05$ HS = highly significant

NB: Numbers in the same column marked with the same letter are not significantly different at the 5% probability threshold (LSD).

Regarding groundnut leaves, the results revealed a significant difference in the chemical compositions of the two varieties. SH 67A had higher CP (16.28%) and NDF (34.36%) contents than ICGV 1276 (14.05% and 40.13%, respectively), whereas ICGV Analysis of variance revealed a significant varietal difference.

The results for sorghum digestibility were 48.79% for the Ponta Negra variety and 49.33% for the Sariasso 16 variety. In Consequence, analysis of variance did not reveal the presence of any significant differences between these elements. However, for groundnut s, the analysis revealed a significant varietal difference in IVOMD, with levels of 55.25% for (ICGV 01276) and 57.88% for (SH 67A).

III. Discussion

III.1. Grain yield and fodder biomass evaluation

The difference in grain yield can be explained by the genetic potential of the varieties used. The yields obtained were higher than those recorded by OUÉDRAOGO (2019), who reported yields of 1704.411 kg/ha and 1110.948 kg/ha respectively for Sariasso 16 and Ponta Négra, under similar conditions.

For groundnut, higher value of seed yields were higher recorded for variety ICGV 1276 variety, which could be explained by its genetic potential. Similar results have been previously reported by authors, such as BETDOGO *et al.* (2015), OTENG-FRIMPONG et al. (2015), and DATTA et al. (2018). According to these authors, groundnut seed yields vary depending on the variety used, ranging from 0.2 to 5.7 t/ha. Furthermore, the results obtained were in the current study higher than those reported by AKANZA and N'GUESSAN (2017) in northern Côte d'Ivoire, with an average yield of 730 kg/ha. This difference could be due to the different agroecological environments of production, varieties, and their drought resistance. Indeed, RAM et al. (2018) and VALA et al. (2018) have shown that the agronomic potential of groundnuts is the result of the genetic potential of the varieties grown, as well as the agro-ecological environments. It also depends on the sowing density, disease management, and soil fertility.

Base on the cropping system, intercropping decreased the yields of sorghum and groundnut compared to when grown alone. OBULBIGA et al. (2015) and COULIBALY et al. (2017) found that cereal–legume intercropping significantly reduced grain and forage yields compared to monoculture during the first year of the study. These low yields could be explained by interspecific competition between varieties for environmental resources. The biomass yield components were higher than those reported by ZORMA (2017) in the Sahelian zone of Burkina Faso. This difference may be related to the differences of agro-pedological and climatic conditions between the two studies. In addition, these results are comparable to those reported by OUÉDRAOGO (2019) in Saria, with forage yields of 4396.831 kg DM/ha and 8371.018 kg DM/ha for Sariasso 16 and the Ponta Negra variety, respectively. For groundnut, the ICGV 1276 variety produced the best yields. This difference could be due to the variety, weed management capacity, and pathologies, which differ between varieties, as highlighted by PRIYA et al. (2015) and VALA et al. (2018). Similar results were found by BETDOGO et al. (2015), OTENG-FRIMPONG et al. (2015), and DATTA et al. (2018), who estimated that leaf yield varies between 0.2 and 11.7 t/ha depending on the variety.

The reductions in forage yields observed in combination are thought to be due to competition for nutrients, sowing density, and the ability of certain plants to be effective in combination. Our results corroborate those of OBULBIGA et al. (2015). They noted that in terms of straw and leaf production, intercropping significantly reduced the yield of each component compared to pure cultivation.

III.2. Effect of intercropping on the agronomic performance of varieties

The grain yield obtained for total EAR corroborate those of other authors, such as OBULBIGA et al. (2015) and AKANZA and N'GUESSAN (2017). These authors showed that combinations were more productive than single-species crops of the corresponding cereals and legumes. These gains, resulting from multi-species cropping, can be explained by the beneficial complementary and facilitating relationships between associated species in the use and exploitation of environmental resources (water, light, nitrogen, and nutrients), as reported by JUSTES et al. (2014). Therefore, crop association allows better use of arable land and improve grain yields compared to monoculture for certain combinations.

In general, crop association has made it possible to increase forage yields and make better use of arable land. Numerous experiments conducted on the functioning of crop combinations have shown that, in general, there is a better use of environmental resources compared to corresponding single-species crops, leading to higher productivity in terms of total biomass produced by the combination (BENIDER, 2018). Furthermore, according to CORRE-HELLOU et al. (2013), the robustness of combinations in the face of biotic and abiotic constraints allows an increase of for a 20% in productivity compared to pure crops. Groundnut variety SH 67A appears to be more effective for the combination in terms of yield, implying better niche complementarity for the exploitation of environmental resources with the associated sorghum than does ICGV 01276.

These yield gains were corroborated by the SCPI values, which were higher for both grain and fodder in the mixtures than in the corresponding monocultures. Similar results were obtained by SANFO et al. (2023a) and SANFO et al. (2023b). These advantages in terms of combinations could be explained by the beneficial and complementary relationships between the different crops in the exploitation and the valorisation of environmental resources, particularly nitrogen (JUSTES et al., 2014; BÉNIDER, 2018; SANFO et al., 2023a et 2023b). This niche complementarity between the two associated species in terms of nitrogen use explains largely the generally superior performance observed for associations compared to single-species cropping (BENIDER 2018). Intercropping improves yield levels through better complementarity between associated species, which reduces competition for nutrients and optimizes their competitiveness.

III.3. Effect of intercropping on weed control

The evolution of weed density differed between treatments, with higher density in intercropping. Our results differ from those obtained by CHIKOYE et al. (2001), who showed that legumes can smother weeds when used in combination as cover crops. In addition, BYBEE and RYAN (2018) reported that intercropping reduced weed growth in the plots. OSWALD et al. (2002) in western Kenya found similar results when intercropping maize with legumes to

control striga (*Striga hermontica*). Our results could be explained by the fact that the ground cover capacity of legumes depends on the species, their stage of development, species, the sowing density, and on the sowing delay between varieties. Indeed, other authors such as CHIKOYE et al. (2001) and OSWALD et al. (2002) have reported higher density in staggered sowing combinations than in simultaneous sowing combinations.

The results obtained for weed biomass revealed a significant difference between the different treatments. In general, multi-species crops appear to be more effective in reducing weed biomass than single specie cropping. Our results confirm those of ESPOIR et al. (2013), who reported that soybean (*Glycine max*) used as a cover crop in combination with maize reduced weed growth. Several phenomena could explain these observations: the complementarity of the species grown in combination, which allows them to use available resources more efficiently by limiting weeds' access to those same resources; the ground cover provided by legumes, which smothers weeds; and the presence of sorghum, which reduces the amount of light, water, and minerals available to weeds, as shown by CORRE-HELLOU et al. (2011) in the case of other species combinations. Therefore, this combination has a greater potential to improve situations in which pure cultivation performs poorly. Thus, the decision to create seed mixtures has an inhibitory effect on weed growth.

III.4. Sorghum and groundnut nutritive value as fodder

The CP content obtained for sorghum was generally low. These results show the same trends as those reported by ZAMPALIGRÉ et al. (2021), with contents ranging from 2.55 to 7% for other sorghum varieties. However, these values are lower than those reported by ZORMA (2017), who obtained contents of 10.18% and 7.78%, respectively, for sorghum variety Sariasso 16. This difference may be related to the agroecological production environment, soil fertility, and climatic variations, as these authors conducted their studies in different agroecological zones of the country. Regarding nitrogen content, our results are below the minimum nitrogen content (7% DM) below which rumen microflora cannot function efficiently (KLEIN et al., 2014). This could be explained by the fact that the soil is not rich enough in assimilable elements, which are the main determinants of the nutritional value of plant and grain fodder (SAINJU et al., 2019). This situation is exacerbated by the high levels of parietal constituents.

For groundnut, SH 67A had a higher CP content than ICGV 01276. This difference could be attributed to genetics background, or to agro-ecological environment of production, as reported by ANSAH et al. (2017) and OTENG-FRIMPONG et al. (2015). According to these authors, the CP composition of groundnut leaves differs between varieties, ranging from 8.5 to 18%.

The IVOMD results indicated that SH 67A had better digestibility than ICGV 01276, and no difference was observed in sorghum. The energy value of forages varies mainly according to the digestibility of the gross energy they contain, which is closely linked to the digestibility of organic matter. The results obtained for sorghum were lower than those reported by other authors, such as ZORMA (2017), with values of 54%, 53.66%, and 58.81%, respectively. However, ELSEED et al. (2007) reported effective degradation of dry matter in different cultivars ranging from 44.4% to 67.7%, which covers a similar range to our results. The variability in digestibility values can be attributed to differences in cell wall concentration and forage harvest stage. BERTRAND et al. (2019) and BHANDARI et al. (2023) indicated that nitrogen concentration and cell wall polysaccharides determine the digestibility of a crop. In contrast, BANI et al. (2007) recorded an inverse relationship between forage fiber fractions and DM digestibility.

The difference observed in groundnuts could be explained by the low content of parietal elements and a higher CP content in SH 67A. According to BERTRAND et al. (2019), the digestibility of organic matter in a forage plant depends mainly on its plant wall content and digestibility. They added that the digestibility of cell walls varies between 40 and 90%, depending on the amount of lignin that they contain.

The groundnut varieties used have good chemical composition and digestibility. They would be excellent fodder for solving the productivity problems of domestic animals. Supplementation is necessary to increase the ingestibility and nutritional quality of sorghum.

Conclusion

This study highlighted the forage potential of improved sorghum and peanut varieties and the effect of intercropping on enhancing the quality of forage supply for livestock. The results show that, despite a relative reduction in unit yields of grain and biomass compared to monocultures, mixed cropping systems have generally made better use of cultivable land, resulting in gains in productivity and resource efficiency. Among the varieties tested, Ponta Negra sorghum stood out for forage production, while Sariasso 16 showed the best grain yields. For groundnut s, the ICGV 1276 variety performed better in terms of both seeds and leaves, while SH 67A proved to be superior in terms of haulm quality.

In terms of quality, groundnut leaves proved to be richer in crude protein and more digestible than sorghum straw, confirming their value as a supplement in animal feed. In addition, the crop combination helped to reduce weed biomass, which had a beneficial effect on weed management.

These results highlight the importance of using improved dual-purpose varieties and promoting sorghum-groundnut combinations as a sustainable strategy for improving fodder supply and strengthening the resilience in livestock systems. However, further research incorporating organo-mineral fertilization and seedling management could further optimize the productivity and quality of fodder from these combinations.

Conflict of Interest:

The authors declare that they have no conflict of interest in the publication.

Author Contribution

DBJ: Methodological design, data curation, as well as first manuscript drafting, revision, and editing. ZN: Contribution to study's conceptual and methodological design, as well as first manuscript drafting, revision, editing, and country project coordination. GLMY and MI: Contributed to data collection and curation. VBY: Contributed to manuscript revision and editing. All authors contributed to the article and approved the submitted version.

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